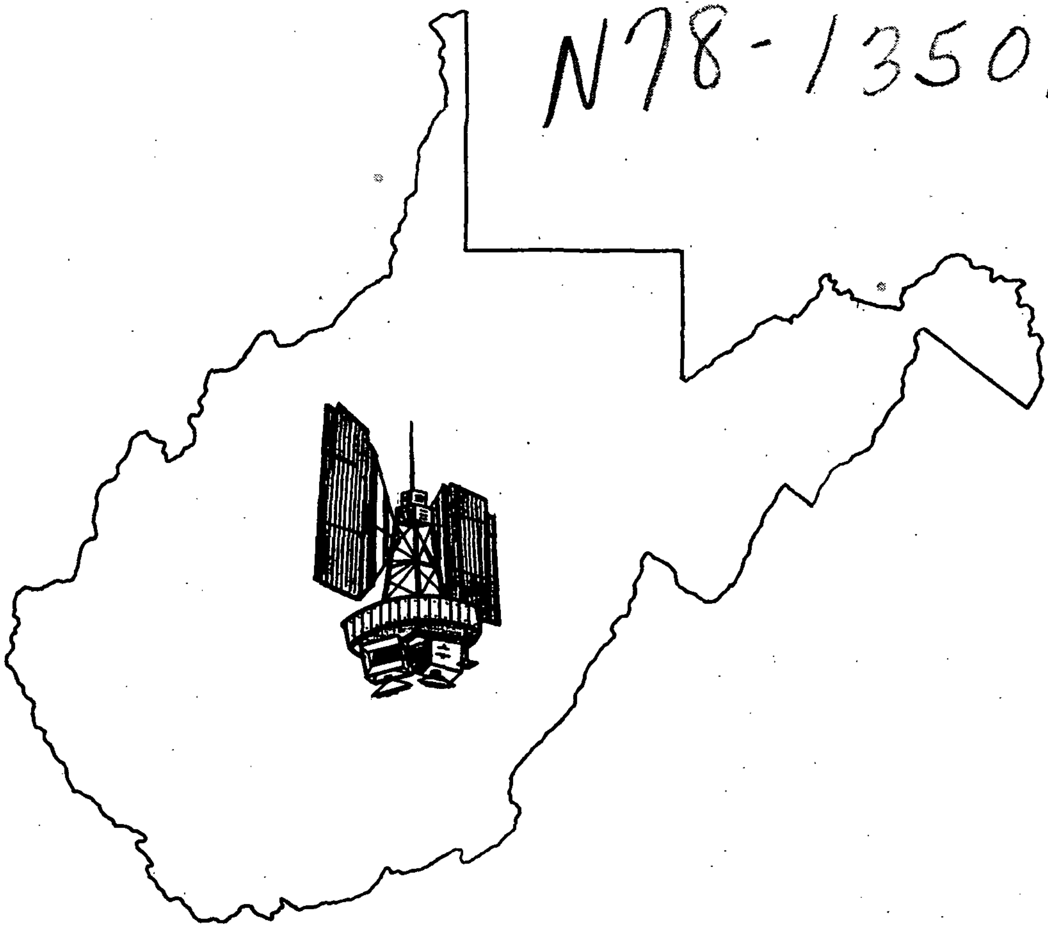
CR-156677 DRA

CONTRIBUTIONS OF LANDSAT TO NATURAL RESOURCE PROTECTION AND FUTURE RECREATIONAL DEVELOPMENT IN THE STATE OF WEST VIRGINIA

N78-13501



FINAL REPORT
Contract No. NAS5-22327
June 1975 through October 1977

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center, Greenbelt, Maryland 20771

CONTRIBUTIONS OF LANDSAT
TO NATURAL RESOURCE PROTECTION
AND FUTURE RECREATIONAL DEVELOPMENT
IN THE STATE OF WEST VIRGINIA

October 31, 1977

TYPE III REPORT

June 1975 through October 1977

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Goddard Space Flight Center, Greenbelt, Maryland 20771

Prepared by:

WEST VIRGINIA DEPARTMENT OF NATURAL RESOURCES

DIVISION OF PARKS AND RECREATION

1800 Washington Street, E., Charleston, West Virginia 25305

CONTENTS

PREFACE

The purpose of the investigation described in this report is to demonstrate to active or potential users of remote sensing technology, some of the capabilities of the Landsat Satellite System for providing useful information concerning environmental and recreational evaluation and planning for the wise use of West Virginia's natural resources.

Manual interpretation techniques of Landsat visible and near infrared bulk processed and computer enhanced imagery, and high and low altitude color and color infrared aircraft photography were used to conduct this investigation. Although the main type of imagery used was from Landsat, the comparison of the different types of imagery has allowed a better understanding of the multistage approach to remote sensing which seems to be the best approach when introducing potential users to remote sensing concepts.

Results of the investigation are favorable towards the West Virginia Department of Natural Resources' use of Landsat imagery for some environmental assessment situations, regional recreation planning, and the use of Landsat ecological base maps as an educational tool at some of the recreation facilities for teaching environmental awareness concepts to visitors.

It will be the responsibility of the various divisions of the Department of Natural Resources to evaluate the work that has been done with Landsat and other types of imagery to this point, and then decide on additional ways in which remote sensing technology can be of benefit to them.

ACKNOWLEDGEMENTS

The investigation described in this report was performed for the National Aeronautics and Space Administration by the West Virginia Department of Natural Resources and the Earth Satellite Corporation under Contract No. NAS5-22327. The Technical Monitor for the project was Mr. Harold Oseroff of Goddard Space Flight Center.

Overall direction in the study was provided by Ira S. Latimer, Jr. and David C. Callaghan who served as Principal Investigators. Assistance of much importance came from Rodney W. Clay, Kermit McKeever, H. G. Woodrum, Donald R. Andrews, George E. Wise, Jr., Lewis Q. Baxter, Gregory M. Luke, and various other Department of Natural Resources' personnel. Also, Mr. Daniel J. Deely, Lawrence Pettinger, Robert Macomber, David Nichols, Dr. Richard Anderson, William Stohlman and staff from the Earth Satellite Corporation contributed to the project.

LIST OF ILLUSTRATIONS

LIST OF TABLES

Table Numbers | *Page*

1. *INTRODUCTION*

The State of West Virginia has long been identified by the news media with the controversy concerning exploitation of its coal resources and the reclamation of its strip mined lands. Less serious attention has been given the existing pressure on (and future development of) recreation resources which are of considerable importance to the state. The responsibility for satisfying the state's recreation needs lies with the West Virginia Department of Natural Resources.

Outdoor recreation and other environmental demands in West Virginia, as in the nation, will increase significantly by the year 2,000. Contributions to this expansion are increased population, increased leisure time, more disposable income, technological advances, creation of new recreation areas, the promotion of attractive existing and proposed recreation areas, and a more urbanized population supported by new industries.

From the standpoint of economic advantage, West Virginia's location is strategic. Four of the nation's five largest metropolitan centers and 55 percent of the country's population lie within 500 miles of its borders (Figure 1). West Virginia is surrounded by nine states with a total combined population of 49 million in 1960 and a projected population of some 60 million by 1980. These growing population centers and, in general, the rapidly developing eastern megalopolis generate an increasing demand for recreation from West Virginia's vast natural resources.

To ensure that the state's resources provide a high quality recreation experience, the Department of Natural Resources has conducted a thorough examination of existing recreation facilities as well as the

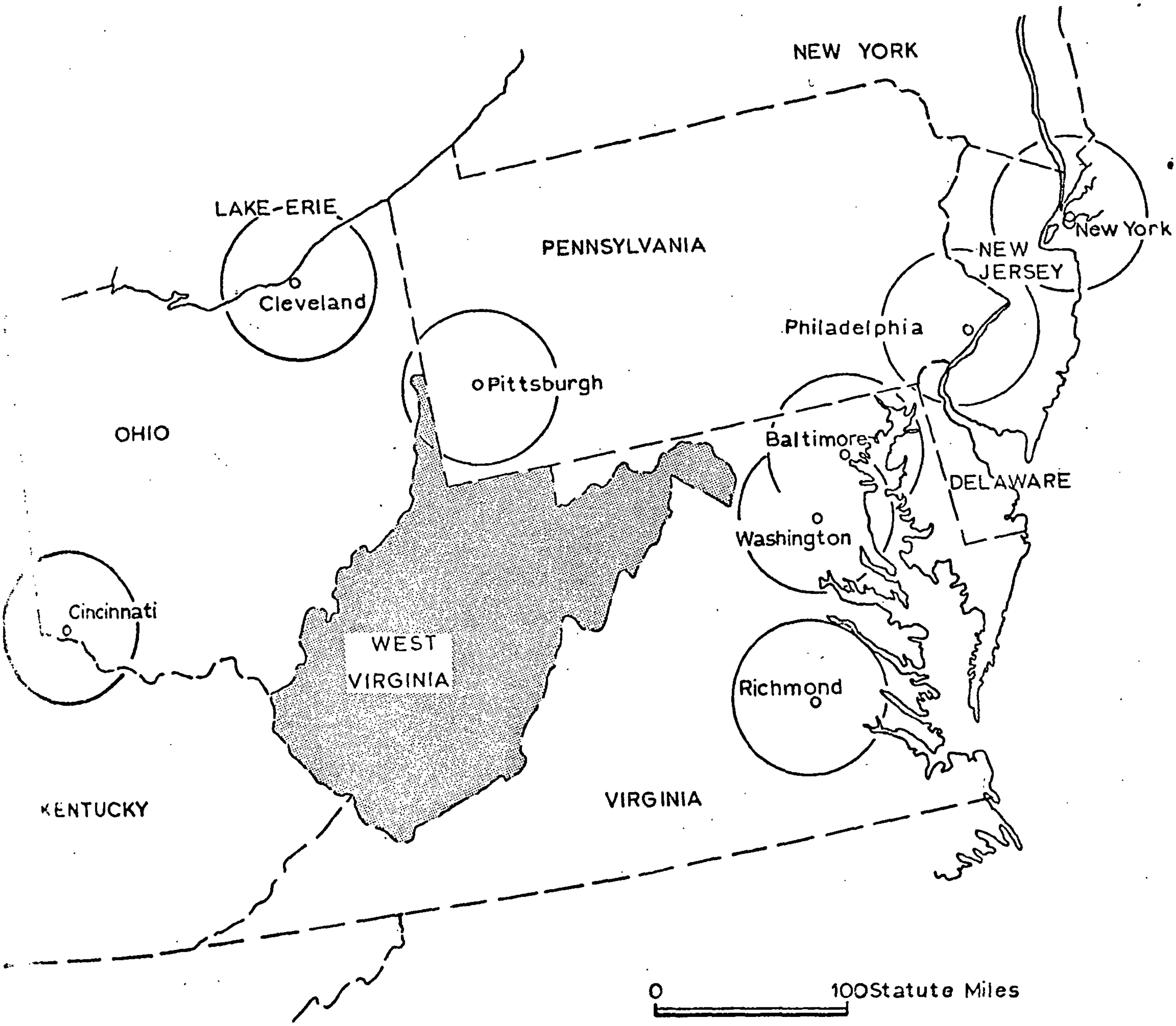


FIGURE 1-1 West Virginia and major metropolitan areas.

supply and demand for recreation resources. The results of this examination are incorporated in West Virginia's Statewide Comprehensive Outdoor Recreation Plan (SCORP).

It is very important that the Statewide Comprehensive Outdoor Recreation Plan contain accurate information about the recreation and environmental resources of the state. If the SCORP concept is to be accurate and useful, periodic re-evaluations should be made to analyze the environmental and recreational trends or changes that occur in the state.

The realization of the need for land cover analysis, environmental monitoring of natural resources, and the establishment of some long range planning concepts for economic, and recreational growth and development in West Virginia inspired the idea of using the Landsat Satellite System for gathering information concerning these issues.

1.1 Applications of Landsat Data for Land Cover Analysis

The Landsat satellite is designed primarily to view the earth's surface rather than the atmosphere around the earth. Its specialty is the collection of information concerning land cover analysis.

The initial space craft in the Landsat series was placed into orbit at a height of about 900 km in late July, 1972. The second spacecraft, Landsat-2, was placed in operation in January, 1975. The principal sensor system onboard Landsat, the Multi-spectral Scanner Subsystem (MSS), observes in four bands, which are in the visible and near-infrared portions of the spectrum. The four bands are designated as the MSS-4 (green, 0.5-0.6 um), MSS-5 (red, 0.6-0.7 um), MSS-6 (red/near infrared, 0.7-0.8 um), MSS-7 (near-infrared, 0.8-1.1 um). Observations are only available during the daytime.

Landsat views an area 185 km side, which is a narrow swath when compared to other satellite systems. Because of the relatively narrow swath, the satellite does not provide daily coverage. At low and mid-latitudes, Landsat repeats coverage of the same area every 18 days (at mid-latitudes, some overlap does occur from one day to the next). With two spacecraft in operation, repeated coverage occurs every nine days.

Various land use and land cover studies are being done with Landsat and other remote sensing data. A few studies that will be referred to during the West Virginia investigation include: A Land-Use Classification System for Use with Remote Sensor Data - by James R. Anderson; Remote Sensing: Terrain Analysis - by D. F. Acton; A Comparison of Two Basic Theories of Land Classification and Their Adaptability to Regional Photo Interpretation Key Techniques - by Gordon R. Heath; and Cornell Aerial Photo Inventories of Urban Land Use and Natural Resources - by John T. Roach.

2. BACKGROUND

On January 31, 1973, the West Virginia Department of Natural Resources submitted a project proposal to the National Aeronautics and Space Administration entitled, "The Contribution of ERTS-B To Natural Resource Protection and Future Recreational Development In The State Of West Virginia."

It was hypothesized that Landsat-2 data could be used in West Virginia to (a) provide current information essential to comprehensive recreation resource management and the protection of endangered landscapes and riverscapes; and (b) make a significant contribution to the implementation of key work elements of the approved state master plan for recreation development (SCORP) by providing a basis for timely Department of Natural Resources' decision making related to recreation resources and environmental protection.

During the time differential between the submission of the Landsat Proposal, the launching and establishment of the operational Landsat-2 System (1975), and signing the contract for the project between NASA and the DNR (1975), several changes had occurred within West Virginia which would affect a few of the concepts in the original Landsat Project Proposal.

The first event that influenced the course of the Landsat Investigation was the Land Use Data and Analysis (LUDA) Program which is being sponsored by the United States Geological Survey and the West Virginia Geological and Economic Survey. This program will map the state using a land cover classification system established by the USGS. Most of the land use mapping will be done by direct photo interpretation of NASA

high-altitude color infrared photography, USGS photography or Sky-lab photography.

To avoid duplication of effort in making land cover maps, the Landsat objectives were modified slightly to concentrate more on specific applications of Landsat on test sites smaller in size than originally planned, but more indicative of the recreational or environmental concerns in question.

The second event which modified the direction of a few Landsat objectives was the updating of some parts of the State Comprehensive Outdoor Recreation Plan before the Landsat Program was started. Some of these completions were: (a) the classification of major waterways under a Land Classification System and ecozone framework (for example) as wild, recreational, or scenic rivers; and (b) to inventory and monitor natural lakes and man-made impoundments to assess their recreation potential. Although these objectives were completed before Landsat-2 was launched, the Landsat System can be used in the future to monitor some of these waterways and water bodies.

The last factor that influenced the Landsat Program was an increase in costs during the time interval between when the program was proposed (1973) and when it started (1975). The cost increase of the program affected the test site area which could be studied.

3. PURPOSE AND OBJECTIVES

The purpose of this investigation was to demonstrate some of the applications of the Landsat System for obtaining information concerning the environment, to be used for recreation planning and environmental management of West Virginia's natural resources.

The detailed objectives, which will be addressed within detailed study areas (consisting mainly of Harrison, Pocahontas, Webster, Randolph and Tucker Counties) are as follows:

(a) To develop a recreation resources data base for the DNR (annotated resource maps and reference imagery).

(b) To differentiate regions of ecological homogeneity (ecozones) within a mountain area based on geological, vegetative, and hydrological inter-relationships.

(c) To identify and map land use patterns and ecologically unique natural resources within ecozones to support effective state land acquisition and protection programs intended to preserve selected resource areas.

(d) To inventory and map surface mining disturbances and associated mining--environmental features for evaluation of mining effects and to aid in the identification of mined lands for acquisition and recreation consideration by the appropriate agency or private entity.

(e) To provide resource data inputs for preparing or reviewing regional environmental impact judgments concerning regional recreational areas within the state in response to the Department of Natural Resources' management needs.

(f) To develop a data bank of Landsat and aircraft imagery and a team of experienced Landsat data users within the West Virginia Department of Natural Resources.

The DNR also has a series of secondary projects which represent the start of the objective to develop a team of remote sensing technicians who will work on projects for the different divisions.

(a) The first project involves the use of satellite imagery and high altitude aerial photography maps in various state parks and forests for the purpose of updating vegetation maps and teaching ecology.

(b) The next project is the development of a set of manually interpreted satellite image maps, at a scale of 1:250,000, designating significant land cover situations in the state.

(c) Another project utilizes high altitude color infrared photography to provide land cover information about areas being considered for recreation development.

(d) A project to inventory forest fire burned sites in the southwest part of the state.

(e) A reference file of satellite imagery and high altitude color infrared photography is being developed.

(f) The Landsat Program is cooperating with the West Virginia Heritage Trust Program of the Department of Natural Resources which is designed to inventory unique ecological areas in the state.

(g) Various presentations and workshops have been given to colleges, conservation groups, and government agencies in an effort to stimulate interest and involvement in the modern remote sensing movement.

(h) *Also a Remote Sensing Handbook has been completed from presentations given at the two remote sensing workshops which were held in May, 1976, and additional information which is considered valuable for potential remote sensing users.*

4. DATA SAMPLED

4.1 Data Acquisition and Search Procedure

Most of the data used for this 28 month investigation was ordered from the Earth Resources Observation System (EROS) facilities at Sioux Falls, South Dakota through an account established by NASA.

Besides the individual orders placed at EROS, a standing account was established to automatically provide satellite imagery of good quality and less than 10 percent cloud cover to the Department of Natural Resources.

4.2 Landsat Data

Fifteen Landsat images were chosen for the primary and secondary projects in various formats, and processed by several different techniques depending on the type of information required from the imagery. The dates and image identification numbers for these scenes are shown in Table 4-1.

The cloud cover problems over West Virginia made it difficult to obtain quality Landsat imagery for certain times of the year. Particular problems were noticed for summer and late fall imagery.

4.3 Aircraft Data

Much of the high and low altitude color and color infrared photography was either ordered from EROS or taken by personnel of the Earth Satellite Corporation (shown in Tables 4-2 through 4-4), with the photolab work being done by EarthSat. The photography scale varied from 1:12,000 to 1:130,000 depending on the project.

4.4 Correlative Data

Various types of support data were used for the projects including

topographic maps, aeronautical charts, reference books, soils maps, personal interviews, and miscellaneous information.

TABLE 4-1

SUMMARY OF LANDSAT IMAGES SELECTED

FROM THE EROS DATA CENTER

	Date	Image ID No.
1.	September 2, 1973	1406-15300
2.	October 26, 1973	1460-15284-1
3.	April 23, 1976	2457-15203-1
4.	September, 1973	1405-15242
5.	September, 1973	1406-15300
6.	September, 1973	1406-15303
7.	September, 1973	1407-15352
8.	September, 1973	1407-15355
9.	September, 1973	1407-15361
10.	September, 1973	1408-15413
11.	September, 1973	1408-15415
12.	September, 1973	1459-15223
13.	October 22, 1974	1821-15245-1
14.	October 25, 1973	1459-15230-2
15.	October 27, 1973	1461-15343-1

Note: Cloud cover problems made it mandatory to use more Landsat I imagery than Landsat II.

TABLE 4-2

SUMMARY OF LOW ALTITUDE AERIAL

PHOTOGRAPHY SELECTED FOR THE INVESTIGATION

	Date	Film Format	Film Type	Frames
1.	October, 1976	70mm	CIR	75
2.	August, 1976	70mm	CIR	75
3.	July, 1976	70mm	CIR	75

TABLE 4-3

SUMMARY OF GROUND LEVEL PHOTOGRAPHY

SELECTED FOR THE INVESTIGATION

	Date	Film Format	Film Type	Frames
1.	July, 1976	35mm	Color	72

TABLE 4-4

SUMMARY OF THE HIGH ALTITUDE AERIAL

PHOTOGRAPHS SELECTED FOR THE INVESTIGATION

	Date	Film Type	Image Frame No.
1.	December 3, 1973	CIR	6954
2.	December 3, 1973	CIR	6955
3.	December 3, 1973	CIR	6956
4.	December 3, 1973	CIR	6961
5.	December 3, 1973	CIR	6972
6.	December 3, 1973	CIR	6973
7.	December 3, 1973	CIR	6974
8.	December 3, 1973	CIR	6975
9.	December 3, 1973	CIR	6985
10.	December 3, 1973	CIR	6986
11.	December 3, 1973	CIR	7096
12.	December 3, 1973	CIR	7148
13.	December 3, 1973	CIR	7149
14.	December 3, 1973	CIR	7050
15.	December 3, 1973	CIR	7054
16.	December 3, 1973	CIR	7055
17.	December 3, 1973	CIR	7086
18.	December 3, 1973	CIR	7087
19.	December 3, 1973	CIR	7088
20.	December 3, 1973	CIR	7089
21.	December 3, 1973	CIR	7090
22.	February 21, 1975	CIR	3269
23.	February 21, 1975	CIR	3270
24.	February 21, 1975	CIR	3271
25.	February 21, 1975	CIR	3323
26.	February 21, 1975	CIR	3324
27.	February 21, 1975	CIR	3325
28.	February 21, 1975	CIR	3326
29.	February 21, 1975	CIR	3327
30.	February 21, 1975	CIR	3373
31.	February 21, 1975	CIR	3374
32.	February 21, 1975	CIR	3375
33.	February 21, 1975	CIR	3429
34.	February 21, 1975	CIR	3430
35.	February 21, 1975	CIR	3431
36.	February 21, 1975	CIR	3432
37.	February 21, 1975	CIR	3433
38.	February 21, 1975	CIR	3434
39.	October 23, 1975	CP	4263

*CP - Color Photography
*CIR - Color Infrared

5. PRIMARY PROJECTS

5.1 Introduction to the Primary Project Concept

The first category of projects involved the primary projects which were technically handled by the Earth Satellite Corporation. These projects utilized Landsat imagery more than those that DNR personnel are developing for the purpose of organizing "in house" remote sensing capabilities. When this Landsat Investigation started, the Department of Natural Resources did not have the technical expertise necessary to complete the primary projects.

5.2 The West Virginia Landsat Satellite Image Mosaic

5.2.1 Objectives of the Project

(a) *To contribute information to a resource data base for the DNR (an annotated resource map and reference imagery).*

(b) *To differentiate regions of ecological homogeneity (ecozones) within a mountain area based on geologic, vegetative, and hydrologic inter-relationships.*

(c) *To identify and map land use patterns and ecologically unique natural resources within ecozones to support effective state land acquisition and protection programs intended to preserve selected resource areas.*

(d) *To provide a satellite image mosaic of the state, as an educational tool to demonstrate what West Virginia looks like from outer space.*

5.2.2 *Data Sampled*

5.2.2.1 *Landsat Data*

	Date	*ID No.*
1.	*September 1973*	*1405-15242*
2.	*September, 1973*	*1406-15300*
3.	*September, 1973*	*1406-15303*
4.	*September, 1973*	*1407-15352*
5.	*September, 1973*	*1407-15355*
6.	*September, 1973*	*1407-15361*
7.	*September, 1973*	*1408-15413*
8.	*September, 1973*	*1408-15415*
9.	*September, 1973*	*1459-15223*

5.2.2.2 *Correlative Data*

1. *Aeronautical charts*
2. *Topographic maps*
3. *Reference books*

5.2.3 *Procedure and Techniques*

(a) *This project utilized Landsat false color infrared images (bands 4, 5, 7) of good quality with less than 10 percent cloud cover taken during September, 1973.*

(b) *After the satellite images, at a scale of 1:1,000,000 were chosen, pieced together and glued in mosaic form, the state boundaries and other important features were delineated from aeronautical charts, and transferred to the mosaic product.*

(c) *The mosaic was then enlarged to a scale of 1:500,000.*

(d) *Lines were drawn around categories that looked different on the mosaic.*

(e) *Classifications were assigned to each of the delineations.*

(f) *After the preliminary delineations were made, the classification system was criticized. (No reference books were used at this stage.)*

(g) *The next step was to gather reference material about state's ecology. Books included were: Vegetation Maps of the United States, by Kuchler; The Principles of Geomorphology, by Thornbury; Physiographic Regions of the United States, by Lobeck; Regional Geomorphology of the United States, by Thornbury; and geologic, landform and topographic maps.*

(h) *The mosaic was divided into one of the three following land categories: Open, wooded and mixed. Analysis of color tones and texture of the images allowed the differentiation categories to be classified.*

5.2.4 *Results of the Project*

Delineations made on the satellite image mosaic and outlined in Table 5.2.4-1 show surface landforms and land cover situations in West Virginia which can be identified on September, 1973, satellite imagery. A mosaic made from a set of imagery from another season might yield different information, but single season, cloud-free imagery was not available for the whole state at the time the project was started.

This mosaic did not contribute as much information about West Virginia's ecology as the DNR had expected. Therefore, the objective of establishing a strong resource data base was weakened.

TABLE 5.2.4-1

LANDSAT MOSAIC CLASSIFICATION CHART

I. *Ridge and Valley Province*

II. *Appalachian Plateau Province*

- A. *Allegheny Mountain Section*
- B. *Unglaciated Allegheny Plateau Section*
    - a. *Blueridge Woodlands*
    - b. *Blueridge Appalachian Valley*
    - c. *Allegheny Woodlands*
    - d. *Appalachian Woodlands*
    - e. *Ohio River Floodplain*
    - f. *Parkersburg Alluvial Farmland*
    - g. *Kanawha River Floodplain*
    - h. *Teays River Valley*
    - i. *Southwest Surface Mining District*
    - j. *West/Central Alluvial Farmlands*
        - 1. *Predominantly Cleared*
        - 2. *Predominantly Wooded*
        - 3. *Mixed*

TABLE 5.2.4-1a

LANDSAT MOSAIC CLASSIFICATION CHART

I. *Ridge and Valley Province - This classification refers to a major landform division as discussed in Regional Geomorphology of the United States by William D. Thornbury. The region is that of the eastern section of West Virginia. It is characterized by parallel valleys of a narrow nature bounded by parallel ridges. The overall relief is high in this area. It stretches from the eastern sections of the state, west to the Allegheny front.*

II. *Appalachian Plateau Province - This is a second major landform as delineated and discussed by Thornbury. The region is west of the Allegheny front and includes sub-sections A and B on the classification chart. It is characterized by high mountains in the east and lower rolling terrain in the west.*

A. *Allegheny Mountain Section - Area of mountainous terrain, generally wooded, high mountains bounded on the east by the Allegheny front and on the west by laurel and chestnut ridges extending south into Pocahontas County.*

B. *Unglaciated Allegheny Plateau Section - Area west of the Allegheny Mountain section. The relief in this area is less, and the degree of dissection is greater, with a drainage density much greater and more erratic than in the Allegheny Mountain Section. (Thornbury)*

a. *Blueridge Woodlands - (EarthSat interpretation) This area applies to the wooded area on the west slope of the Blueridge Mountains east of the Shenandoah River valley.*

TABLE 5.2.4-1a

LANDSAT MOSAIC CLASSIFICATION CHART

b. *Blueridge Appalachian Valley* - *(EarthSat interpretation) A wide valley stretching from the Shenandoah River west to the first ridge west of Martinsburg, West Virginia.*

c. *Allegheny Woodlands* - *(EarthSat interpretation) Area in the Allegheny Mountains which is chiefly wooded.*

d. *Appalachian Woodlands* - *(EarthSat interpretation) Wooded area in the Appalachian Mountains east of the Allegheny front, on the Landsat imagery as a dark red color.*

e. *Ohio River Floodplain* - *(EarthSat interpretation) Area along the western border of the state distinguishable on Landsat when viewed in stereo, characterized by a very light pink.*

f. *Parkersburg Alluvial Farmland* - *(EarthSat interpretation) Initially observed on the Geologic Map of the State of West Virginia as an area of alluvial deposition by the Ohio River. It shows up on Landsat because of greater dissection and cultural development, and is delineated as a triangular area around Parkersburg, West Virginia.*

g. *Kanawha River Floodplain* - *(EarthSat interpretation) This area appears on Landsat and the West Virginia geological maps as an area having a great amount of cultural development because of the fertility of the soil.*

h. *Teays River Valley* - *(Thornbury interpretation) This area is an ancient channel of the Teays River which is the predecessor of the Ohio River. Stream piracy of the*

old Teays River led to the formation of a now dry river bed which extends from west of Charleston, West Virginia, into Ohio.

i. *<u>Southwest Surface Mining District</u> - (EarthSat interpretation) Area in the southwest portion of the state which is characterized by intense surface mining, chiefly coal, and shows up as a greatly disturbed area west of Beckley, West Virginia, north to Kanawha River and south to the West Virginia border.*

j. *<u>West/Central Alluvial Farmlands</u> - (EarthSat interpretation) Large area distinguished on Landsat by its degree of cultural dissection and on West Virginia geological maps as a large area of alluvium.*

The categories (1) predominantly cleared, (2) predominantly wooded, and (3) mixed, apply to the different shades of red and pink visible on the Landsat mosaic. They indicate different degrees of clearing of the forest once covering the State of West Virginia. Those areas that are predominantly cleared were marked as such and appear as large white or pink colored areas on the Landsat mosaic. Those that are predominantly wooded are marked by their large dark red color and the mixed areas are those in which the combination of categories (1) and (2) were so intense that separate delineations of (1) and (2) were impractical.

5.2.5 Use of the Project

The mosaic represents the first interpreted Landsat Satellite view of West Virginia. This is an important point to make because in the future, other mosaics could be made to show changes occurring in the state.

The mosaic will be used as an educational product to show ecological, cultural and physiographic aspects of the state. Copies will be displayed in some of the state parks to teach visitors about the natural resources of the state.

5.3 Canaan Valley-Dolly Sods Project

5.3.1 Introduction

Canaan Valley is an elongated, oval-shaped valley nestled high in the Allegheny Mountains in the northeast section of Tucker County, West Virginia (30^{o} 05'N latitude and 90^{o} 25'W longitude). The valley and the immediately adjacent areas are covered by the Davis, Mount Storm Lake, Blackwater Falls and Blackbird Knob, West Virginia 7.5 minute topographic quadrangles(USGS, 1967). Canaan Valley may be reached by taking State Route 32 south from Davis, Tucker County. Route 32 crosses the south end of the valley approximately five miles from Davis.

An ecologically distinguishing feature of the Canaan Valley area is the extent of the wetlands on the valley floor. The total area of freshwater wetlands in Canaan Valley, approximately 6,000 acres, is the largest of any area in the central

Appalachian Mountains. Once forested, these wetlands presently support extensive bogs, wet meadows, and swamps. The remaining better drained upland areas are vegetated chiefly by forb and grass meadows and hardwood forests characterized by sugar maple (Acer Sacharum), beech (Fagus Grandifolia), and black cherry (Prunus Serotina). Naturally, regenerated red spruce standing today occupy only the upper slopes of the mountains encircling the valley.

A large portion of the flora is composed of plants with distinctly northern ranges and distribution. For a few, Canaan Valley represents the southernmost extension of their ranges. In view of the relatively large number of thriving "northern species", the flora of Canaan can be considered boreal in its overall composition.

The Dolly Sods area is noteworthy botanically because of the variety of plant communities it supports, many of them similar to those found at sea level in eastern Canada. The high plateau country is becoming well known because of its resemblance to country near the Arctic Circle, and because the scarcity of trees provides many outstanding scenic vistas.

Much of the high plateau region is occupied by what botanists call heath barrens, known locally as "huckleberry plains". Exposed rocks are covered by a variety of shrubs, including blueberries, huckleberries, azalea, laurel, chokecherry and

speckled alder with scattered red spruce. Meadows cover other portions of the "high country". The well known Dolly Sods is about one mile square, but larger meadows are found in the northern half of the North Fork Watershed and the southern end of Roaring Plains.

Bogs dominated by hummocks of sphagnum and polytrichium moss occupy poorly drained portions of the plateau, especially in the watershed of the North Fork of Red Creek. The largest is about a mile long and up to a half mile wide. Many of the plants in these bogs are the same species as those found in the tundras of the Arctic. Cranberries, tiny carnivorous sundew plants, and orchids grow in them; a variety of ferns, sedges, and occasional balsam fir occupy the margins. Usually beaver ponds are associated with these bogs.

A proposed Highland Scenic Highway has been tentatively routed through the area. Those who value the Dolly Sods because of its remoteness and botanical significance are protesting. There are definite plans for an impoundment on the high plateau to serve as the upper reservoir for a pumped storage electric facility to be used in conjunction with a proposed 7,200 acre reservoir in the Canaan Valley. Many people believe this "lake" will have great recreational potential, and the crest of Cabin Mountain has been suggested as an ideal site for vacation homes. At the other extreme, conservationists have urged the Forest Service to set more of the Dolly Sods area aside as an eastern wilderness area.

5.3.2 *Objectives of the Project*

(a) *To identify and map land use patterns and ecologically unique natural resources within ecozones to support effective state land acquisition and protection programs intended to preserve selected resource areas.*

(b) *To provide resource data inputs for preparing or reviewing regional environmental impact judgments concerning local and regional recreational areas within the state in response to the Department of Natural Resources management needs.*

(c) *To develop a recreation resources data base for the DNR.*

(d) *To provide ecological information for the naturalist programs at Blackwater Falls and Canaan Valley State Parks.*

5.3.3 *Data Sampled*

5.3.3.1 *Landsat Data*

	Date	ID No.
1.	September 14, 1973	1406-15300
2.	October 26, 1973	1460-15284-01

5.3.3.2 *High Altitude Color Infrared Photos*

	Date	Frame No.
1.	December 3, 1973	6954
2.	December 3, 1973	6955
3.	December 3, 1973	6956

5.3.3.3 *Ground Level Color Photography*

	Date	Frames
1.	August, 1976	72

5.3.4 *Procedure and Technique*

5.3.4.1 *The High Altitude Color Infrared Photo Base Map (test site area approximately 9,000 square acres)*

(a) An enlargement of a color infrared high altitude aerial photo, taken December 3, 1973, was made to a nominal scale of 1:24,000.

(b) The photo enlargement was backlighted on a light table and covered with a mylar overlay.

(c) A preliminary information classification system was developed.

(d) The color infrared 9" x 9" transparent photographs at a scale of 1:120,000, were used to interpret information, which was transferred to the photo base map (scale 1:24,000). Signatures were established for features shown on the photograph.

(e) Three field trips were taken to identify features and signatures from the photos.

(f) The delineations were completed and the classification system finalized.

5.3.4.2 *The Landsat Image Diazo Print Enlargement of Canaan Valley-Dolly Sods*

(a) After reviewing several bulk processed satellite image 70mm "chips", the September 2, 1973 overpass was chosen to produce a diazo transparency. (Figure 5.3-1)

(b) Various color combinations were tried with bands 4, 5 and 7 of the satellite imagery to

determine the best combination of colors to use for printing a color composite image which would highlight vegetation cover conditions.

(c) A color was assigned to each of the bands to be used to make the diazo composite at a scale of 1:1,000,000 (band 4 - yellow, band 5 - red, and band 7 - blue).

(d) A 1:1,000,000 scale negative was then enlarged to a 1:250,000 scale positive image for each band and then diazo printed.

(e) A diazo 3 band color composite was used to produce a contact color negative at a scale of 1:250,000 and then enlarged to a scale of 1:24,000 before being printed.

(f) The 1:24,000 scale diazo print was overlayed with a clear plastic land feature map of the Canaan Valley-Dolly Sods area.

(g) On a separate overlay, areas of similar color, texture, and tone were outlined on the diazo print.

(h) Assumptions were made as to what the different delineations were supposed to mean.

(i) The diazo printed satellite image map results as shown in Table 5.3-4 were compared to the color infrared aerial photo base map results (Tables 5.3-1, 5.3-2 and 5.3-3).

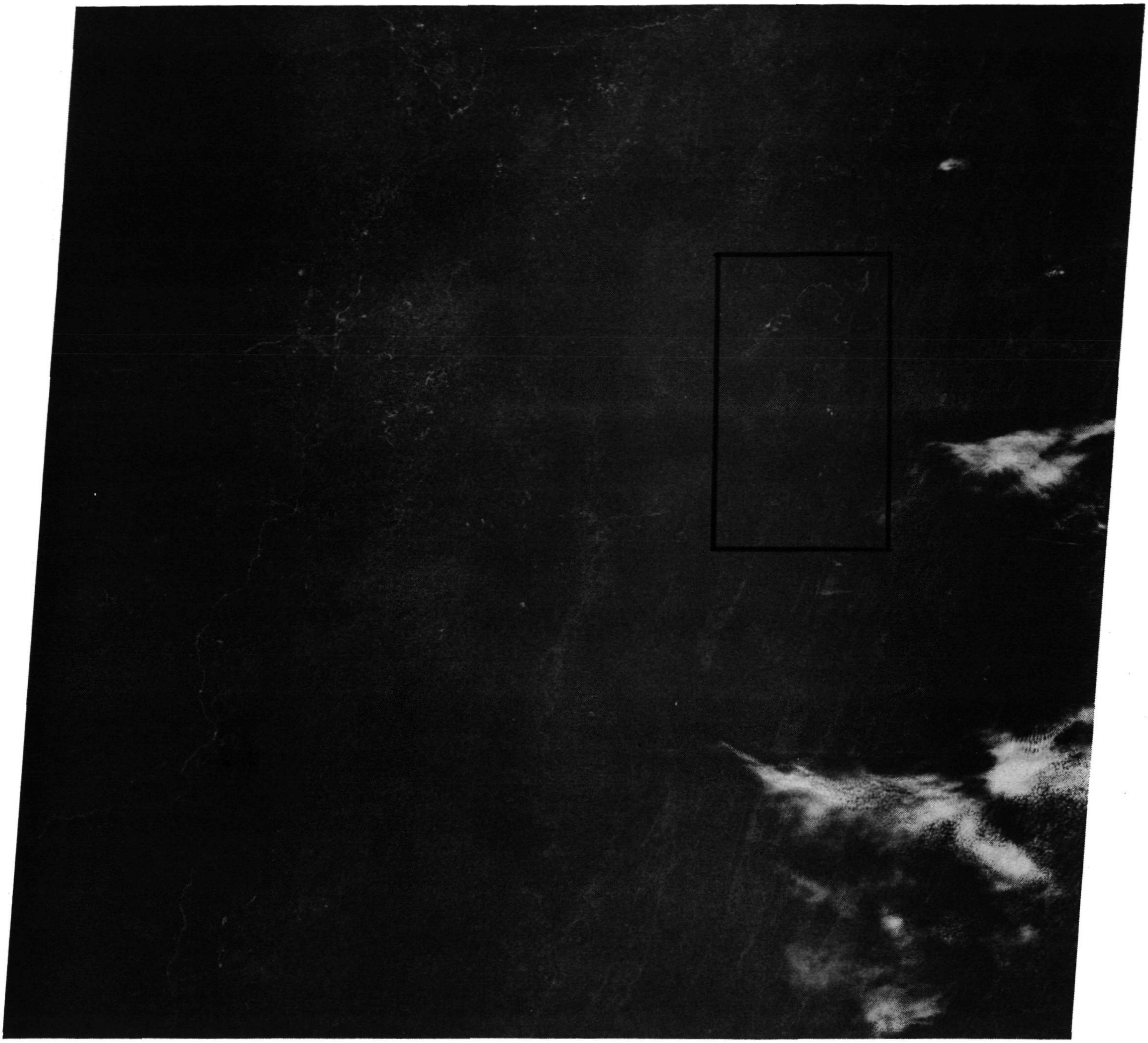


FIGURE 5.3-1 Landsat-1 MSS-7 image (I.D. No. 1406-15300), 2 September 1973, showing the Canaan Valley - Dolly Sods area of West Virginia which was chosen as a test site for part of the recreation resource and environmental inventory study.

TABLE 5.3-1

Land Feature Delineation Results of the Canaan Valley - Dolly Sods Area
(U-2 Map)

Category	Class	Techniques Used To Obtain Results
Land Features	Paved Roads	Land feature results were obtained by photo-interpretation techniques and from topographic maps of the area.
	Unpaved	
	Jeep Trails	
	Foot Trails	
	Beaver Ponds	
	Power or Gas Line Right of Ways	
	Rock Outcrops	
	Park Boundaries	

TABLE 5.3-2

PLANT COMMUNITIES
(U-2 Map)

Vegetation Cover Type	Plant Communities	Explanation
A. Forest	1. Spruce Hemlock	1. This community is associated with the higher elevations of the Canaan Valley-Dolly Sods area.
	2. Northern Hardwood	2. A variety of species can be associated with this community including sugar maple, red maple, beech, basswood, yellow birch, pine, red oak, black cherry, and white ash.
	3. Swamp Forest	3. Area which has a water table at, near, or above the surface of the ground during most of the year. Species would include balsam-fir, red spruce, red maple, yellow birch, and hemlock.
B. Shrub	1. Shrub Swamp	1. Area which has a water table at, near, or above the surface of the ground during most of the year, with low woody stemmed, (usually multi-stemmed), vegetation.
	2. Heath Barren	2. Areas, mostly above 3800 feet in elevation, more or less densely covered with a variety of heath shrubs, (mountain laurel, mountain azalea, huckleberry, and blueberries), and other low-growing plants.
	3. Seral Thicket	

TABLE 5.3-2 cont'd.
(U-2 Map)

Vegetation Cover Type	Plant Communities	Explanation
C. Open	1. Marsh	1. Land which has the water table at or near the surface of the ground during some seasons of the year. Vegetation consists of grasses, cattails, mosses, and low shrubs.
	2. Moss Glade	2. Area that originated as a result of hard rock formations near the surface, which impede the drainage of mountains streams. Vegetation consists of sphagnum moss, heaths, sedges, and cotton grass.
	3. Seral Field	3. Area that has predominantly treeless vegetation and is not cultivated. Types of plants would include grasses, low shrubs, flowers, crabapple, and hawthorne.
	4. Agricultural Field	4. Area that has predominantly treeless vegetation and is cultivated during the year.
	5. Grass Bald	5. Area of naturally - occurring treeless vegetation located on a well - drained site below the climatic treeline in a predominantly forested region. Plants include grasses and heath barrens.

TABLE 5.3-3
(U-2 Map)

Plant Genera Delineation Results of the Canaan Valley - Dolly Sods Area

Genera	Explanation
1. Picea - Spruce	Evergreen trees which are largely restricted to cooler regions of the Northern Hemisphere, and having a primary importance in the manufacture of pulp and paper (ex. red spruce).
2. Tsuga - Hemlock	A medium sized tolerant evergreen tree found in many types of soils, but reaches its best development in cool moist situations (ex. eastern hemlock).
3. Pinus - Pine	The largest and most important genus of the conifers, having a primary importance in the production of timber, pulp and paper (ex. white and red pine.)
4. Betula - Birch	Medium size trees that are largely restricted to cooler regions of the Northern Hemisphere, being medium tolerant (ex. yellow and black).
5. Fagus - Beech	One of the most common tolerant trees of the eastern hardwood forest, forming associations with red spruce, maple, white pine, cherry, northern red oak, and hemlock (ex. American beech).
6. Acer - Maple	Medium size deciduous trees found in association with other northern hardwoods on drier or moderately moist, sandy loam soils, or even on rocky uplands (ex. red maple).
7. Populus - Aspen	A medium size tree found on many types of soils, growing in dense stands in association with other northern hardwoods.
8. Alnus - Alder	A medium size tree growing in pure stands near stream banks, and in canyon bottoms where moisture is plentiful.
9. Prunus - Cherry	A medium size deciduous tree having the best growth on rich soils. Associated with trees like ash, pine, hemlock, spruce, and maples.

TABLE 5.3-3 cont'd.
(U-2 Map)

Genera	Explanation
10. Pyrus	Shrub that grows on open areas which are usually fens or bogs.
11. Kalmia - Laurel	A deciduous, tolerant evergreen plant that grows as a shrub in northern hardwoods at higher elevations.
12. Rhododendron - Rhododendron	A deciduous, tolerant evergreen plant growing in cooler climates on various types of soils in association with northern hardwoods.
13. Vaccinium - Blueberry, Huckleberry, and Cranberry	These shrubs grow at high elevations on well drained, thin soils.
14. Spirea - Pipestem	A shrub that grows in the rich alluvial soil at the edge of the forest and lining the banks of streams.
15. Typha - Cattail	Plants that grow at the edge of slow-moving streams, the shallow water at the margin of ponds and lakes in rich alluvial and organic matter.
16. Polytricum and Sphagnum - Mosses	Mosses that grow on poorly drained treeless areas which are cold, cloudy and wet.
17. Wintergreen	Small evergreen plants growing in higher elevations on dry open wood sites.
18. Assorted Grasses and Composites	These small plants grow in open areas at a variety of elevations as a common type of vegetation.

TABLE 5.3-4

CANAAN VALLEY LANDSAT IMAGE MAP

DELINEATIONS	EXPLANATIONS
A. Moss Glades	Area that originated as a result of hard rock formations near the surface, which impede the drainage of mountain streams. Vegetation consists of sphagnum moss, heaths, sedges and cotton grass.
B. Spruce Forests	The evergreen spruce forests are predominantly found at higher elevations in Canaan Valley mixed with Hemlock and northern hardwoods.
C. Water Bodies	The main water body in the Canaan Valley-Dolly Sods Area is the Stony River Reservoir.
D. Urban Areas	The primary urban area identified in the test site area is the town of Davis, West Virginia.
E. Barren Land	Various surface mines are found in the test site area.

5.3.5 *Results of the Landsat Image and Color Infrared Aerial Photo Maps of Canaan Valley-Dolly Sods Area*

The comparison of results from the Landsat Image Map and the Color Infrared Aerial Photo Map, as shown in Tables 5.3-1 to 5.3-4, has given Department of Natural Resources' personnel a good idea of the information that is available on the enlarged high altitude color infrared aerial photography, and the enlarged bulk processed diazo printed Landsat Imagery. Also, the Department of Natural Resources has learned some of the concepts concerning the multi-stage approach to remote sensing.

The Color Infrared Aerial Photo Map is perhaps one of the most useful projects which was done during this investigation. The level of detail which could be accurately interpreted compares to the standards set up for Levels III-IV information in the U. S. Geological Survey Publication #964 entitled A Land Use and Land Cover Classification System for Use with Remote Sensor Data.

The satellite image map which was enlarged to a scale of 1:24,000 provided five classes of information. The classes were general ones such as moss glades, spruce forests, water bodies, urban areas and barren land. At such a large scale, the satellite image was not a dependable source of information about Canaan Valley. A more practical photographic product to use would have been a photographic print of the imagery at a scale of 1:125,000.

Information on landform and land use patterns is available from Landsat and is useful in a change detection mode if a good base map is first prepared. Landsat information is limited by the interpreter's knowledge of the area as well as by its own resolution.

5.3.6 *Use of the Project*

This project represents one of the most practical applications of high altitude color infrared aerial photography and Landsat Satellite imagery for natural resource identification and evaluation in West Virginia. The manual interpretation of remote sensing techniques that were demonstrated and the information gathered about Canaan Valley and Dolly Sods are being used in a variety of ways.

Perhaps one of the most important uses of this project will be to show the ecological significance of the Canaan Valley-Dolly Sods area. Since the area is being considered for development as a hydroelectrical project (Davis Power Project), the completion of this remote sensing project has come at a time when the issue of the Canaan Valley-Dolly Sods area is being decided by action between various environmental interest groups and the Federal Power Commission. It is hoped that the products of the Landsat Program will be used to give evidence to the ecological significance of the area.

Another very important use of the color infrared aircraft photo base map and Landsat images of the area is the work that is being done in the state parks to educate the visitors to the

concepts of conservation and regional ecology. The nature interpretative programs in the parks will be expanded to include the different ecosystems within a regional ecozone instead of just comparing plant and animal species and their habitat. The total story of how a defined natural area grows, matures and changes can be told more effectively with the aid of a base map that shows land features, plant communities and plant genera of the area.

Copies of the Canaan Valley-Dolly Sods Remote Sensing Project are displayed in the lodges of Blackwater Falls and Canaan Valley State Parks and are being used during visitor orientation and by park naturalists during lectures. Other parks will be inventoried and photo base maps made with the aid of remote sensing techniques.

5.4 West Virginia Wetlands Project

5.4.1 Introduction

Throughout the highest regions of the Appalachian Mountains, from southern New England south to the Great Smokies are wetlands which harbor plants which are seen more in Canada than at these latitudes. In West Virginia, these areas are relatively common at elevations above 3200 feet, but can be found at many elevations.

The Department of Natural Resources is extremely interested in knowing where the wetland areas are in West Virginia. Efforts are now being made to inventory these wetland areas and to establish a classification system which will be compatible with federal wetland legislation.

5.4.2 Objectives of the Project

(a) To organize a remote sensing and wetland classification system for monitoring wetlands in West Virginia.

(b) To inventory the wetlands in the eastern part of the state by remote sensing techniques.

(c) To inventory and map land use patterns and ecologically unique natural resources within ecozones to support effective state land acquisition and protection programs intended to preserve selected resource areas.

5.4.3 Data Sampled

5.4.3.1 Landsat Data

	Date	ID No.
1.	September 14, 1973	1406-15300
2.	October 26, 1973	1460-15284-01

5.4.3.2 *High Altitude Photography*

	Flight	*Date*
1.	73-199	December 3, 1973
2.	75-017A	February 21, 1975
3.	75-018B	February 22, 1975
4.	75-181A	October 21, 1975
5.	75-0181B	October 21, 1975

5.4.3.3 *Low Altitude 70mm Color Infrared Photography*

	Date	*Frames*
1.	July, 1976	1-50

5.4.3.4 *Ground Level Photography*

	Date	*Frames*
1.	Summer 1976	1-72

5.4.4 *Techniques and Procedure*

There are a variety of wetland types in the state, the bulk of which are situated in the eastern portion. General species composition is known, but distribution maps have not been produced. The project was approached in the following manner:

(a) U-2 photography search to locate wetland areas.

(b) Field study.

(c) Development of a wetland classification system.

U-2 Photography Search to Locate Wetland Areas. *Based on a review of the literature and materials supplied by the state, a search of the U-2 photography was initiated to determine imaging characteristics of the state wetlands and to identify other wetland areas which were not listed in the above materials. Table 5.4-1 shows the results of this search and*

identifies specific areas which were studied during three field trips.

The size of the wetlands identified on the photography varied from small (4-10) acres to large areas such as Canaan Valley and the Meadow River which are several hundred acres in area. The color infrared photography was the most useful due to distinct boundaries evident from tonal differences between many wetland types and the surrounding vegetation. However, all available photography of this type was flown in the winter, hence specific signature identification for all wetland types was not possible. A wetland key developed by the state as a result of this work will be very useful for training purposes. In general, the following characteristics of the photography were found useful in locating wetlands.

(a) <u>Tone</u>: This was useful in those areas where some vegetation was living during the winter months. Examples are glade type wetlands in Canaan Valley and meadow wetlands along creeks and rivers.

(b) <u>Topography</u>: Very important for smaller wetland units where depressions and other low areas may be identified by stereoscopic viewing of the photography. Used as corroborative evidence when tentative identification has been made by tone or texture and for direct location of wetland areas.

<u>Field Study</u>. Approximately three man-weeks were spent in field investigation of wetland sites. Areas were selected for

intensive study on the following:

(a) Data supplied by the state.

(b) Literature review.

(c) U-2 photography analysis.

An attempt was made to ground survey as many different wetland types as possible in order to evaluate remote sensing techniques for defining each type and also to develop a workable wetland classification system. Figure 5.4-1 is a map of the state, showing areas where field work was conducted. Table 5.4-1 lists names of sites visited within each area keyed to Figure 5.4-1. In many cases, sites were extremely difficult to get to and required jeep transportation and long walks.

A review of available data indicated that the bulk of wetland occurs in the eastern part of the state. Evaluation from aerial photography showed the western part of the state having small streams which dissect steeply sloping hills, terrain which is not conducive to development of large wetland areas. The scale of the photography was not sufficient to resolve wetlands along these small streams.

Routine methodology developed by EarthSat for wetland field work was utilized in the project. This included laboratory preparation time for locating wetland units on aerial photography, making of Polaroid prints from aerial photography and planning of field effort. Field work included tone analysis of aerial photographs, transects through wetland

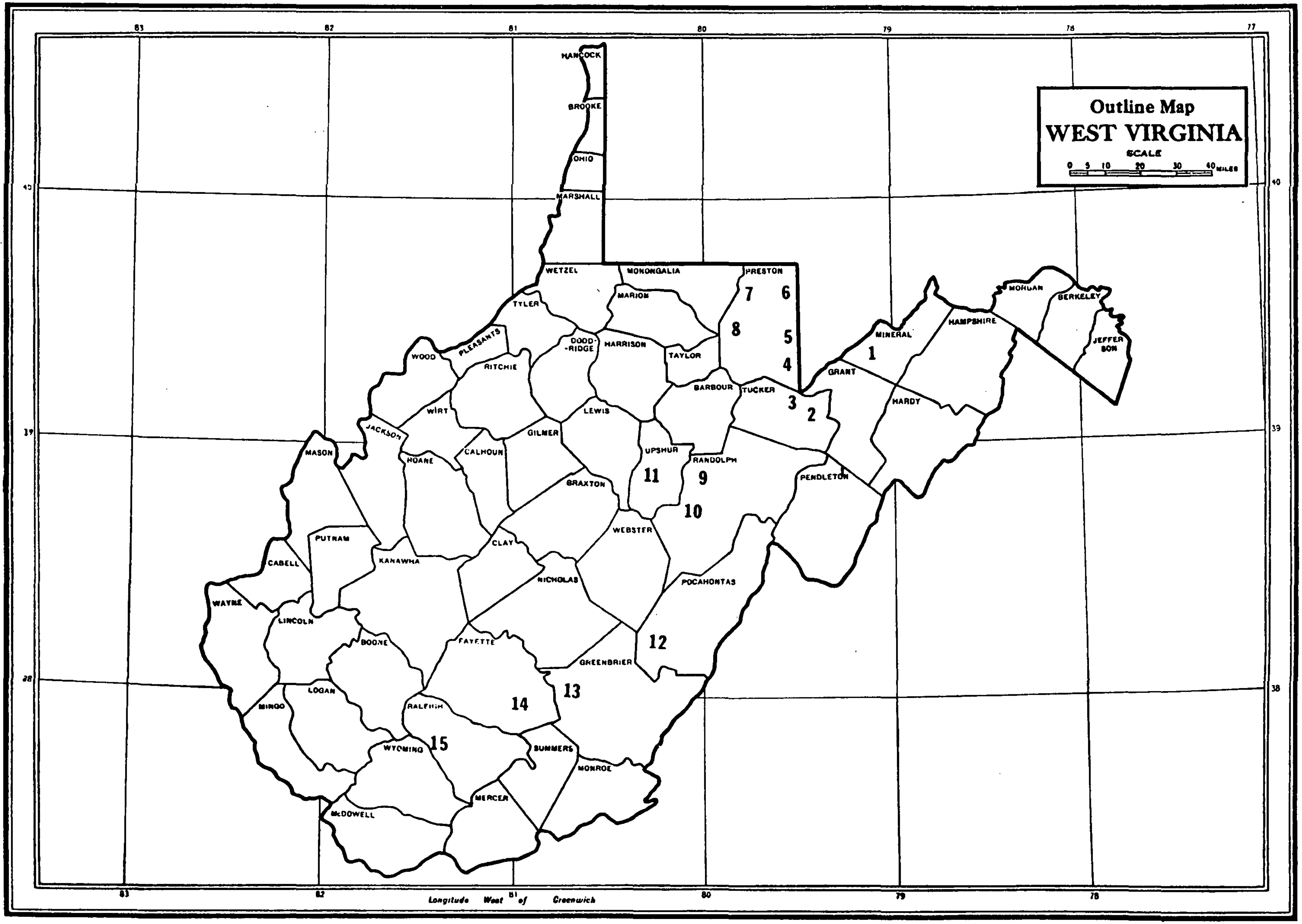


FIGURE 5.4-1 Map showing general location of sites where field work was conducted on wetlands.

TABLE 5.4-1

WETLAND SITES ANALYZED IN FIELD AND CROSS-REFERENCED TO U-2 PHOTOGRAPHY

Map Reference Number	Site Names	Flight	Frames	Wetland Class(es)
1	Keyser New Creek			D SWd
2	Canaan Valley Blackwater River at State Park	75-018B 75-017A 73-199	3386-88 3269,70 6955,56	D MLW R R EWm SW
3	Davis Pendleton Creek	75-181A	4212,13	D D D D MLW, EWm, Ew, SW
	Lost Run	"	"	D D MLW, EW
	Beaver Creek	"	"	D EWm
	Elder Swamp	75-01813 73-199	3388,89 6955,56	D D D MLW, EWm, EW D SW
4	Aurora Wolf Creek Rhine Creek	75-017A "	3456,57 "	D D EWm, SWd

TABLE 5.4-1

WETLAND SITES ANALYZED IN FIELD AND CROSS-REFERENCED TO U-2 PHOTOGRAPHY

Map Reference Number	Site Names	Flight	Frames	Wetland Class(es)
5	Terra Alta/Hopemont Terra Alta	75-017A	3454,55	L L L EWma, EWm, SWd
	Alpine Lake (below)	"	"	D D EWm, SWd
	Saltick Run	"	"	" "
	South Branch Creek	"	"	" "
	North Branch Creek	"	"	" "
	Mountain Run	"	"	" "
	Cranesville Swamp	73199 75-017A	7140 3082,3380	D D D MLW, SWd, FWd, EWm
6	Hazelton/Brandonville Hog Run	75-017A	3399/3452, 53/3080/81	D D SWd, EWm
	Hazel Run	"	"	
	Cherry Run	"	"	D D SWd, EWm

TABLE 5.4-1

WETLAND SITES ANALYZED IN FIELD AND CROSS-REFERENCED TO U-2 PHOTOGRAPHY

Map Reference Number	Site Names	Flight	Frames	Wetland Class(es)
6	Glade Run	75-017A	3154,55	D FWd
7	Hopewell Laurel Run Little Laurel Run			D D SWd, FWd
8	Masontown Deckers Creek	75017A	3449,50	R D EWma, EWm
	Swamp Run	"	"	R D FWd, SWd
9/10	Elkins/Beverly Tygart Valley River	73-199	6967-69	D D D SWd, EWm, EWma
11	Rock Cave Little Kanawha River	73-199	7005	D SWd
12	Cranberry Glades	73-199	7011,12	D MLW
	Cranberry River	75-017A	3356	R SWd
13	Rupert Meadow River Meadow River	75-017A	3121,3192,94 3418,19	R D D D SWd, SWd, EWm,EWma
		73-199	7018-20	D D FWd, SBv

TABLE 5.4-1

WETLAND SITES ANALYZED IN FIELD AND CROSS-REFERENCED
TO U-2 PHOTOGRAPHY

Map Reference Number	Site Names	Flight	Frames	Wetland Class(es)
14	Danese Smokey Branch Laurel Creek	73-199	7050,51	D D SWd, EWm
15	Bolt Maple Meadow Creek Breckenridge Creek	73-199	7088	D D SWd, EWm

units and making of generalized species maps for later reference.

<u>Wetland Classification System</u>. A relatively large number of regional and national classification systems have been developed to confront the problem of a need to categorize wetlands with regard to value for wildlife management purposes, etc. None of these were designed for use where remotely sensed data would be the primary source of information. The most recent work is the U. S. Fish and Wildlife Service Interim Classification of Wetlands and Aquatic Habitats of the United States. It is a hierarchical system based on plant "life form" and allows for use of remotely sensed data, as well as ground information. The State of West Virginia developed a "Classification Field Manual" based on an earlier draft of the U. S. Fish and Wildlife system.

The classification system developed by EarthSat for this project (Figure 5.4-3 to 5.4-6) is a modification of the U. S. Fish and Wildlife Service system and incorporates some elements of the West Virginia field manual. The format of this proposed system is recommended by EarthSat since it closely resembles that which will probably be used in a national wetland survey.

The major EarthSat modification is the addition of water regime modifiers in a hierarchical form which the national system does not provide. In order to evaluate water regime from aerial photography, one must define certain terms in order to fit this specialized and limited data base. Three of the U. S.

TABLE 5.4-2

Synopsis of wetland categories observed as a result of ground survey

Ecological System	Ecological Class	Ecological Subclass	Definition
R	EW	m	Riverine, emergent wetland, meadow
	EW	ma	" " " , marsh
	SW	d	" , shrub wetland, deciduous
	FW	d	" , forested wetland, deciduous
L	EW	m	Lacustrine, emergent wetland, meadow
		ma	Lacustrine, emergent wetland, marsh
D	SB	v	Palustrine, submergent bed, vascular
	EW	m	Palustrine, emergent wetland, meadow
		ma	Palustrine, emergent wetland, marsh
	MLW	-	Palustrine, moss/lichen wetland
	SW	d	Palustrine, shrub wetland, deciduous
	FW	d	Palustrine, forested wetland, deciduous

FIGURE 5.4-3 WEST VIRGINIA WETLAND SURVEY

Prototype Inventory Legend

(Based on Interim Classification of Wetland and Aquatic Habitats of the United States FWS - 1976)

ECOLOGICAL SYSTEM	R - RIVERINE	L - LACUSTRINE	D-PALUSTRINE
ECOLOGICAL SUBSYSTEM	3. High Gradient Reach	4. Low Gradient Reach	7. Profundal 8. Littoral
ECOLOGICAL CLASS	B Bottom FL Flat BB Beach/Bar RS Rocky Shore	P Pool RI Riffles SB Submergent Bed FLB Floating-Leaved Bed	EW Emergent Wetland MLW Moss/lichen Wetland SW Shrub Wetland FW Forested Wetland
ECOLOGICAL SUBCLASS	f Fine c Coarse r Rock o Organic	v Vascular al Algal a Attached ff Free Floating	m Meadow ma Marsh e Evergreen d Deciduous
ECOLOGICAL ORDER	15 Mineral 16 Organic		
WATER REGIME CLASS	F Flooded	D Saturated	I Intermittantly Flooded
WATER REGIME SUBCLASS	e Temporarily s Seasonally	g Semipermanently h Permanently	a Irregularly

Water Chemistry Regime Modifiers may be applied to orders, subclasses, or classes.

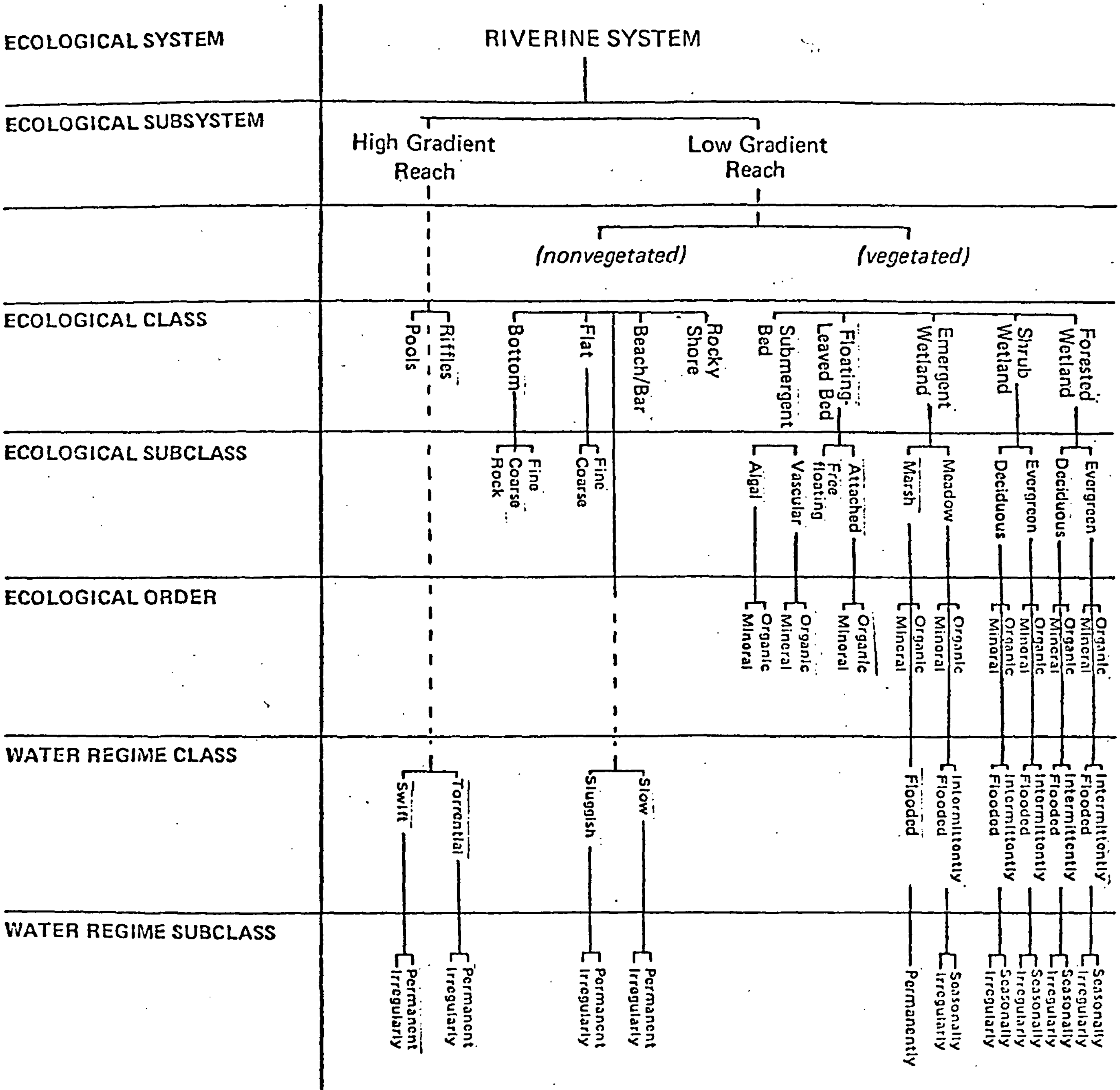
30 Hypersaline	pH modifiers for all fresh waters
35 Saline	
40 Near-Saline	55 Acid Fresh
45 Moderatley Saline	60 Circumneutral Fresh
50 Slightly Saline	65 Alkaline Fresh

Special Modifiers may be applied to orders, subclasses or classes.

I Impoundment	C Canal	Ir Irrigated	F Farmed
D Dugout	Ch Channelized		

FIGURE 5.4-4 WEST VIRGINIA WETLAND SURVEY

Prototype Classification System *



VEGETATION CLASS	List of species, typically occurring in each Ecological Class or Subclass for Riverine Systems in West Virginia.
VEGETATION SUBCLASS	Species composition of each Ecological Class or Subclass derived principally from ground survey.

*Dr. Richard R. Anderson, Earth Satellite Corporation

FIGURE 5.4-5 WEST VIRGINIA WETLAND SURVEY

Prototype Classification System

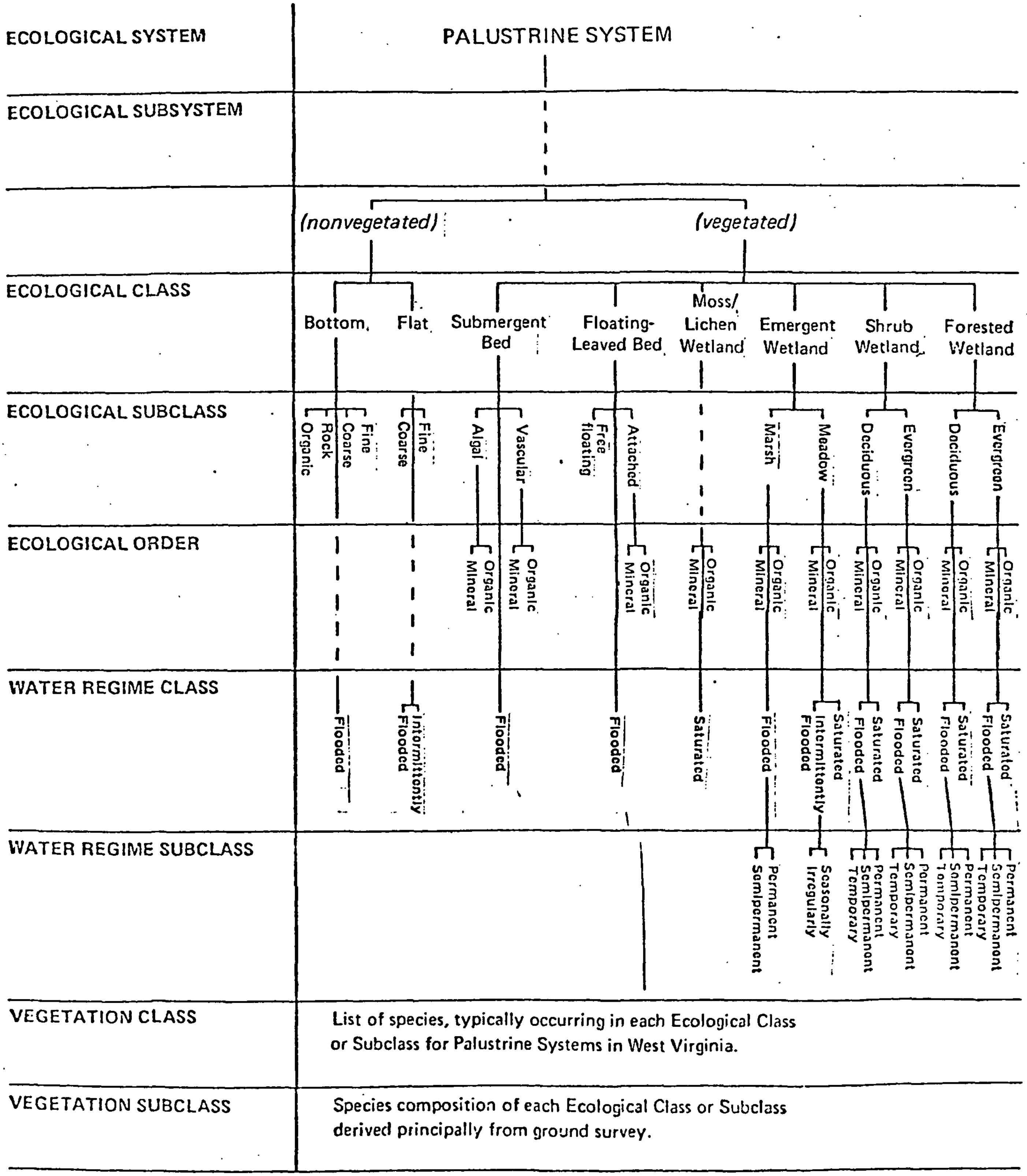
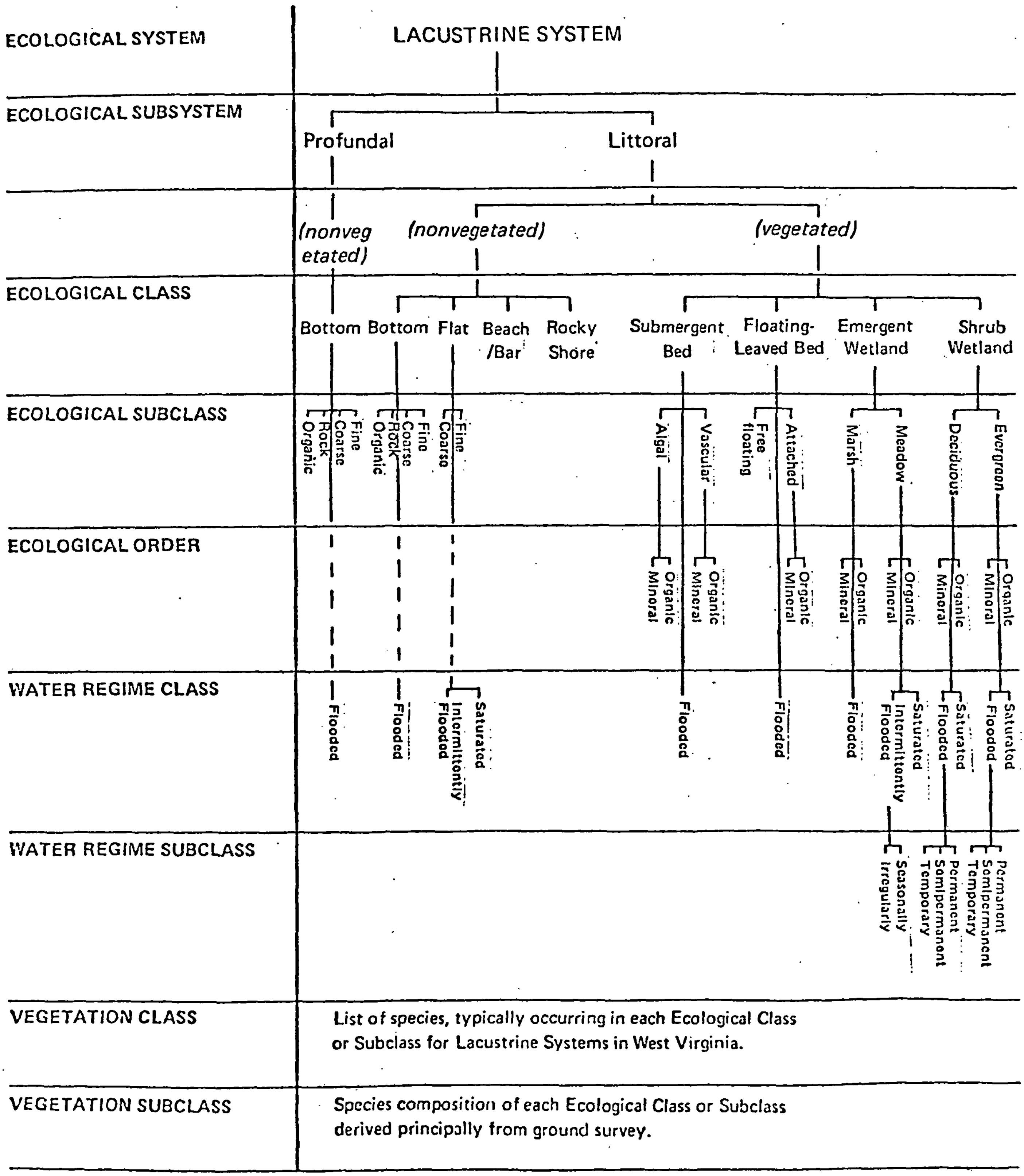


FIGURE 5.4-6 WEST VIRGINIA WETLAND SURVEY

Prototype Classification System



Fish and Wildlife Service terms were selected and redefined in such a way that generalizations may be made from an aerial photograph. These terms are: FLOODED, SATURATED and INTERMITTENTLY FLOODED. These would be used only at the class level. Subsets of these terms would be in the subclass level and normally used only when detailed hydrological information is available. The three class level terms were defined in the following way:

1. *FLOODED: Those areas which have standing water at the time of aerial photographic coverage. The subclass modifiers, such as temporarily flooded or permanently flooded, cannot be identified from a one time coverage of an area. However, careful planning of photographic missions could avoid taking data when many temporarily flooded areas would be present. This could give an excellent account of the amount of open water in the state.*
2. *SATURATED: An area which is identified as wetland by photographic interpretation of topography or vegetation, is not covered by water and is not contiguous with a riverine system.*
3. *INTERMITTENTLY FLOODED: A term reserved principally for those wetlands which are contiguous with riverine systems where it is assumed that periodic flooding occurs, but standing water would not normally be present. May be used for lacustrine and palustrine system where changes in water level may be interpreted from an aerial photograph.*

Two subclass modifiers may be used, seasonally and irregularly, these derived from ground data.

The other areas where the Fish and Wildlife Service system was modified is the Division of Emergent Wetland into Subclass Meadow and Marsh. Although these subclasses are difficult to differentiate from aerial photographs, a high enough degree of accuracy is possible to warrant the attempt.

A Vegetation Class and Subclass was also added by which one can apply plant association information to the classification system. In cases where the species are readily identifiable from the photography, or where the species composition is known, one would go directly to the Subclass level.

This system approximates the old Martin, et al. system in many respects, yet gives the option to apply more detailed information when available. It is a system that has definite applications to an aerial photographic method for data collection, mostly at the class level. It is also closely related to the proposed national system which may be important in the future federal funding of wetland surveys.

The major problems which may be encountered utilizing this classification system will be ones of definition, where class distinction may not be clear. For instance, the distinction between Lacustrine and Palustrine is not always easily made. The U. S. Fish and Wildlife Service definition is based on

shoreline features, size of the catchments and presence or absence of vegetation.

Wetland sites within each area that were field studied, were classified according to the proposed system down to the Ecological Subclass where possible. Table 5.4-1 shows the categories identified for each site. Table 5.4-2 shows a synopsis of the twelve categories observed during the field effort.

5.4.5 Results and Recommendations

5.4.5.1 Usefulness of U-2 Photography for Wetland Classification and Delineation

Color infrared was the most useful of the U-2 photography. Unfortunately, all of this was flown in the winter and, hence, a full evaluation is not possible. Tonal variation in the natural color photography flown during the growing season was not sufficient to discriminate many wetland classes. The usefulness of the CIR photography will be discussed in the context of the proposed wetland classification.

(a) <u>Ecological System.</u> Of the three categories at this level, Lacustrine, Palustrine and Riverine, the Palustrine category will be the most common in the state, as judged by a review of the photography. Most of the Palustrine wetlands in sites 4, 5, 6 and 7 (see Figure 5.4-1 and Table 5.4-1) were identified first on the CIR

photography and then field checked. The small scale photography will present a problem where the accuracy of the upper wetland boundary is critical, particularly where the transition zones are broad.

Only large Riverine wetlands will be resolvable due to the requirement for channel identification. Smaller rivers such as the Blackwater and Cranberry are examples of this problem. Lacustrine wetlands are the least common in the state, but were resolvable with the small scale photography. The boundary between Lacustrine and Palustrine categories may present difficulties, however.

(b) *Ecological Subsystem. No attempt was made to define this category in a large enough sample to be representative of the whole state. It was not possible to evaluate the categories littoral and profundal due to ice conditions.*

(c) *Ecological Class. This class of wetlands is a particularly critical test of a remote sensing technique. Resolution to this level must be possible in order to extract information that has value for management objectives in wetlands. Not all of the categories could be evaluated. For instance, the categories Bottom, Flat,*

Beach/Bar, Rocky Shore, Pools and Riffles would be resolved in only larger Riverine systems at the scale of currently available photography. This type of wetland was not studied in the project. The categories Submergent Bed and Floating-Leaved Bed may have been resolved if the ice conditions had not existed on larger bodies of water. The following is a brief discussion of those categories which were resolved.

1. *Emergent Wetland (EW). This is probably the most widely occurring category in the state. The small scale of photography presented some difficulties in resolution, particularly smaller units, and those where boundaries were broadly transitional from wetland to upland (i.e., the Meadow River). Table 5.4-1 should be consulted for a listing of these sites where this category was resolved on the photography.*

2. *Moss/Lichen Wetland (MLW). This class was resolved on the winter photography due to the distinct tonal structure of the wetland. No problem was encountered identifying this category in several areas, once the signature was learned by the interpreter. Winter photography may be the best for resolving this*

category due to a lack of overstory vegetation at this time.

3. *Shrub Wetland (SW). In most instances, shrub wetlands could be differentiated on the photography. A combination of signature and texture may be used for interpretation. Stereoscopic viewing is a necessary aid in some circumstances to substantiate a shrub wetland identification. The most difficult areas to identify in this category were where the shrubs were relatively young or have a natural low-growth habit.*
4. *Forested Wetland (FW). There was little problem differentiating this category although two of the areas, where identified, were relatively large (Cranesville and Meadow River). The major problems of this scale of photography are boundaries between wetland and upland forests and differentiating young forest from shrub wetland.*

(d) Ecological Subclass. These terms are modifiers to the class categories and in most cases require ground information. The distinction between marsh and meadow was not made from the CIR photography due to snow and ice conditions. Separation may be made by plant species identification, standing water in vegetation or

by intricate drainage pattern which all indicate a marsh wetland. The distinction between deciduous and evergreen was made on the winter photography due to the presence of leaves on the evergreen trees.

5.4.5.2 *Recommendations for Wetland Inventory in West Virginia*

The following recommendations for wetland inventory and mapping using remote sensing as a data base are given with the assumption that existing data will be the primary source of information. These data will be primarily U-2 photography, Landsat and selected low altitude, hand-held photography. Figure 5.4-8 demonstrates what EarthSat feels is a multilevel approach to wetland mapping, with the use of digitally processed Landsat or low altitude photography for updating.

U-2 photography at scales of 1:60,000 and 1:120,000 is available for most of the state. It is relatively high resolution and may be enlarged considerably for production of photo base maps. A 10x enlargement is not unreasonable in terms of photographic quality and would provide wetland detail that would be sufficient for a general inventory. Figure 5.4-9 is a generalization of what level of information could be extracted from the U-2 photography with some ground data support. High resolution digitally processed Landsat data could be used as a primary source of

information in a few cases. It would be most useful, however, as an update mechanism once accurate maps are produced by other means. The most efficient and cost effective means for more detailed information remains low altitude aircraft or helicopter reconnaissance with hand-held photography. This has been used by EarthSat and with experienced interpreters provides a considerable amount of information while limiting the need for extensive and costly ground survey.

5.4.6 Use of the Project

This project will be reviewed by the Department of Natural Resources to determine if the recommendations provided by the report are feasible to use in the West Virginia Wetlands Inventory System.

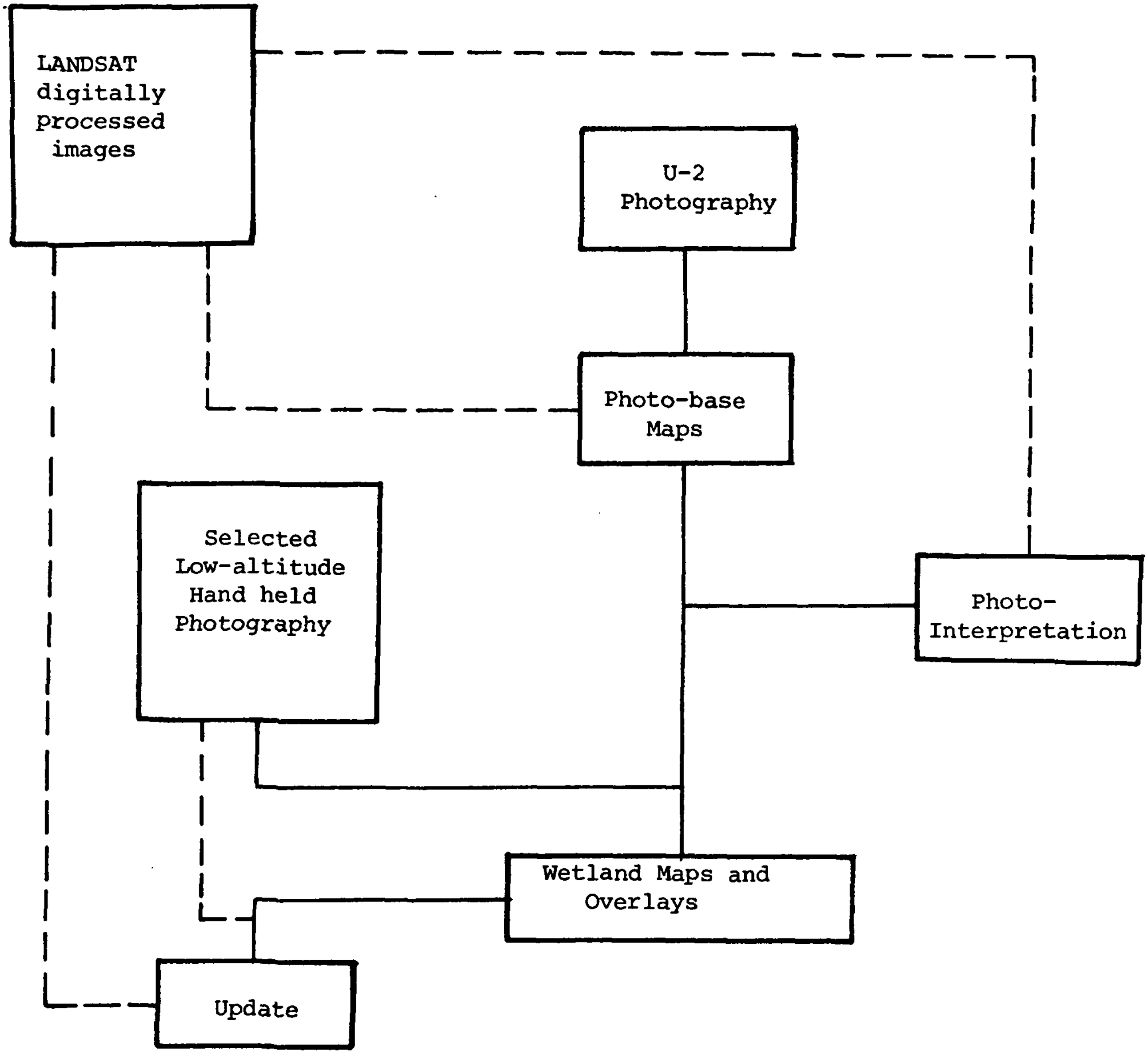


FIGURE 5.4-7 MULTILEVEL APPROACH TO WETLAND MAPPING IN WEST VIRGINIA

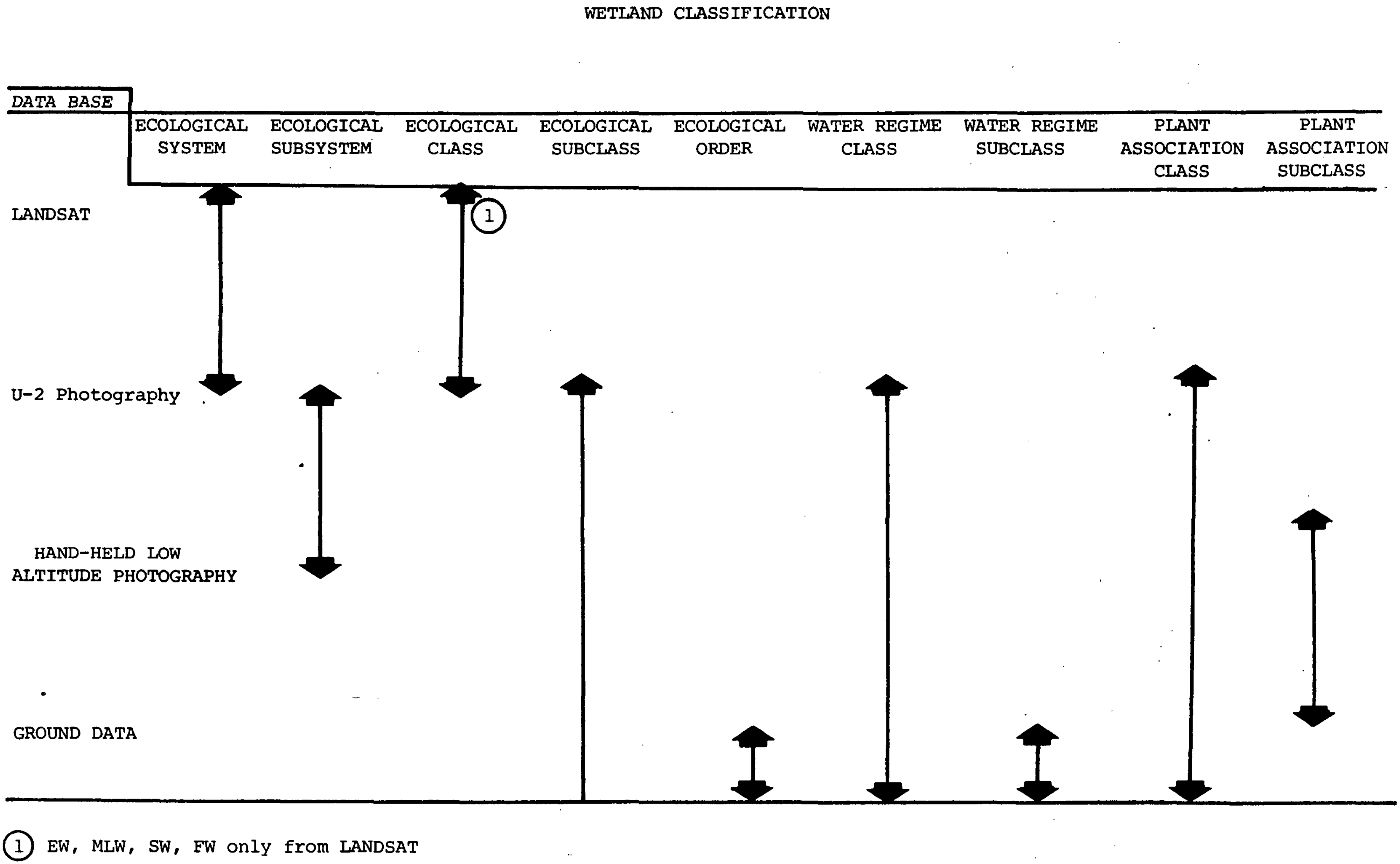


FIGURE 5.4- 8 GENERALIZATION OF LEVEL OF INFORMATION IN WETLAND CLASSES FROM VARIOUS DATA TYPES

5.5 Surface Mine Project

5.5.1 Introduction

West Virginia's leading industry is coal mining which tremendously affects the economy of the state and the nation. The state is ranked sixth in the nation for mineral production and first in production of bituminous coal. Mineable coal is present in 44 of the 55 counties and underlies more than 55 percent of the total area of nearly 25,000 square miles of the state.

The energy crisis caused by a shortage of oil products has lead to a new emphasis on coal for fuel. As the country converts from oil to other energy sources, coal will become very important and West Virginia will play an increasing role in the energy programs of the country.

The removal of minerals must be constantly monitored to protect the environment. A leadership role on mining techniques should come from within the regulatory agencies of the state.

The concern about the environment has lead to controversy concerning surface mining which produces 20 to 25 percent of West Virginia's coal. The Department of Natural Resources has been directly involved in the controversy because it is the regulatory agency in the state which has control over the development of surface mines.

The Landsat Program hopes to provide useful ideas on how the Department of Natural Resources can use remote sensing techniques to study abandoned and active surface mines and

for future reclamation and development of these mined lands possibly as recreation areas, housing developments, small airports, shopping centers and various other projects.

5.5.2 Objectives of the Project

(a) To demonstrate manual interpretation techniques using Landsat and aircraft data for the inventory and mapping of surface mining disturbances and associated environmental features for the evaluation of mining effects and to aid in the identification of mined lands for acquisition and recreation consideration by the appropriate agency or private entity.

5.5.3 Data Sampled

5.5.3.1 Landsat Data

	Date	ID No.
1.	April 23, 1976	2457-15203

5.5.3.2 High Altitude Color Infrared Photos

	Date	Frame No.
1.	December 3, 1973	7087
2.	December 3, 1973	7088
3.	December 3, 1973	7089
4.	December 3, 1973	7090

5.5.3.3 High Altitude Color Photos

	Date	Frame No.
1.	October 21, 1975	4263

5.5.3.4 Low Altitude 70mm Color Infrared Aerial Photos

	Date	Frames
1.	October, 1976	1-75

5.5.3.5 *Landsat Computer Compatible Tape*

	Date	*Image ID*
1.	*April 23, 1976*	*2457-15203*

5.5.4 *Procedure and Technique*

(a) *A test site which is owned by Consolidation Coal Company--Rowland Division on Coal River Mountain in Raleigh County near Beckley, West Virginia, was chosen for its variety of conditions of mined land features. (Permit Numbers shown in Table 5.5.4-1).*

(b) *An enlargement print of a high altitude color aerial photo taken October 21, 1975, was made to a scale of 1:11,520 and covered with a clear plastic mylar overlay.*

(c) *A total area of approximately 10,670 acres was outlined on the aerial photo overlay as a test site featuring a variety of mining and reclamation conditions.*

(d) *Low altitude color infrared 70mm photography taken by the Earth Satellite Corporation in October, 1976, and the enlarged color aerial photo base map were used to map the surface mine test site area by using photo-interpretation techniques. The interpreted information was put on the clear plastic overlay of the enlarged color aerial photo in the classes shown in Table 5.5.4-2.*

(e) *A computer shade print of the test site area was made on an IBM 360-158 computer system from the Landsat Computer Compatible Tape dated April 23, 1976, for band 5 showing various reflectance characteristics of ground surface features. (Image ID 2457-15203)*

TABLE 5.5.4-1

Mining Permit Numbers for the Consolidation Coal Company - Rowland Division Mines in the Coal River Mountain Area of Raleigh County, West Virginia.

	Permit Numbers	Acreage
1.	330 - 68	645.8
2.	188 - 70	857.0
3.	90 - 71	658.0
4.	143 - 71	218.0
5.	11 - 72	241.0
6.	105-72	40.0
7.	157 - 72	185.2
8.	158 - 72	94.8
9.	30 - 74	107.54
10.	134 - 75	26.5
11.	9 - 76	8.6

TABLE 5.5.4-2

COLOR AERIAL PHOTOGRAPHY BASEMAP
CLASSIFICATION SYSTEM

CLASS	EXPLANATION
1. V_1	Areas within the test site with less than 50% coverage of vegetation.
2. V_2	Areas within the test site with greater than 50% coverage of vegetation.
3. A_1	Bare soil area within the test site which has active mining taking place.
4. A_2	Bare soil area within the test site.
5. SP	Sediment pond.

(f) *The intensity levels on the Landsat shade print were compared to the color aerial photo base map to determine a character set for the reflected light intensities, and to determine what combinations of intensity levels could be grouped together to establish classes interpreted on the color aerial photo base map. Tables 5.5.4-3 and 5.5.4-4 illustrate the results of this phase of the surface mine project.*

(g) *To check the accuracy of the aerial photo maps and the satellite's shade print, a field trip was taken to the test site with a DNR reclamation inspector.*

(h) *The next phase involved comparing the classes of information found on the satellite image shade print (image number 2457-15203 taken April 23, 1976) with the classes of information on the color aerial photo base map dated October, 1976.*

(i) *In order to obtain a product from the satellite which would provide a regional picture of the surface mine situation around the test site area, a series of Landsat color composite full frame images made at a scale of 1:250,000, designed to enhance bare soil areas were made. Table 5.5.4-5 describes the images. (See Figure 5.5-1)*

(j) *The last product for the surface mine project was a computer enhanced satellite image made from data collected April 23, 1976 (ID number 2457-15203) and enlarged to a scale of 1:24,000 and 1:48,000. A proprietory digital enlargement algorithm designed by the Earth Satellite*

Corporation was used in an effort to produce a larger negative image without usual limitations inherent in photographic processing or in normal pipe repeat digital enlargements or average enlargements. The routine used performs this operation by using the picture function image recomposition to minimize blocking or squares normally produced by picture element repeat or averaging techniques. This data was then processed using the supervised linear stretch with the appropriate adjustment in each of the data limits by applying the transformation tables generated in the enlargement process. The black-and-white images that were produced were then combined photographically into a color composite image.

5.5.5 Results

The surface mine evaluation work that has been done so far in West Virginia with Landsat has produced some interesting ideas about the concept of using a satellite system to evaluate and monitor surface mines.

The Department of Natural Resources did not have the opportunity to explore the surface mine application possibilities as thoroughly as expected because of the shortage of funds for the project. More work needs to be done with manual interpretation and computer classification techniques to fully evaluate the potential applications.

Results from the classification of information on the Landsat band 5 computer shade print made from data collected April 23,

TABLE 5.5.4-3

Band 5 Shade Print Character Set for Satellite Image
(I.D. 2457-15203)

Intensity Levels	Character Groupings
0-27	Denser vegetation.
28-31	Less dense vegetation.
33	Often indicated haul roads.
35-38	Ungraded spoils.
39-42	Graded spoils.
43-46	Miscellaneous features of high reflectance.

TABLE 5.5.4-4

Band 5 Shade Print Classification System
Satellite Image (I.D. 2457-15203)

Intensity Levels	Classes	Explanations
28-31	V_1	Areas within the test site with less than 50% coverage of vegetation.
0-27	V_2	Areas with the test site with greater than 50% coverage of vegetation.
33-42	A_2	Bare soil area within the test site.

TABLE 5.5.4-5

Satellite Image Products Made From April 23, 1976-Landsat Imagery

Satellite Image	Description of Images	Interpretive Results
A	A photographically enhanced additive color composite of bands 5 and 7 to render strip mines red and pink.	Not enough contrast between shades of green, red and pink. The image appears semi-blurred and does not have the best detail for interpretation.
B	A computer enhanced standard color infrared composite of bands 4, 5, and 7. Digital image processing includes Square, Deskew, Contrast, and Laplacian edge enhancement programs to increase tonal contrast and image sharpness.	This image provides good contrast in color with good definition of detail for bare soil and vegetated areas. The computer enhancement features are quite beneficial.
C	A computer enhanced additive color composite produced by exposing a band 5 positive, band 7 negative sandwich and a band 7 negative to render forested areas dark green, non forested vegetated areas light green and strip mines dark red.	Insufficient contrast in colors for accurate interpretation of surface mine details. The dominant yellow influence is too much for good contrast.

TABLE 5.5.4-5 (Cont.)

Satellite Image Products Made From April 23, 1976-Landsat Imagery

Satellite Image	Description of Images	Interpretive Results
D	Standard color infrared composite of bands 4, 5 and 7 rendering green vegetation in shades of red and strip mines in shades of blue and grey.	This image was a good standard color infrared image with good contrast and color separation for a bulk processed image. Some parts of the image were better than others for interpretive quality.
E	A photographically enhanced three color composite produced by exposing bands 5 and 7 normally and splitting the band 4 exposure between bands 5 and 7 to render vegetation in tones of green to cyan and strip mines in tones of pink.	A good quality image with good contrasts in color showing different conditions of activity on surface mined areas. (i.e. bare soil was a darker red on more active areas in contrast to pink color for less active areas.) Detail was good for larger bare soil sites, but decreased for less active sites.

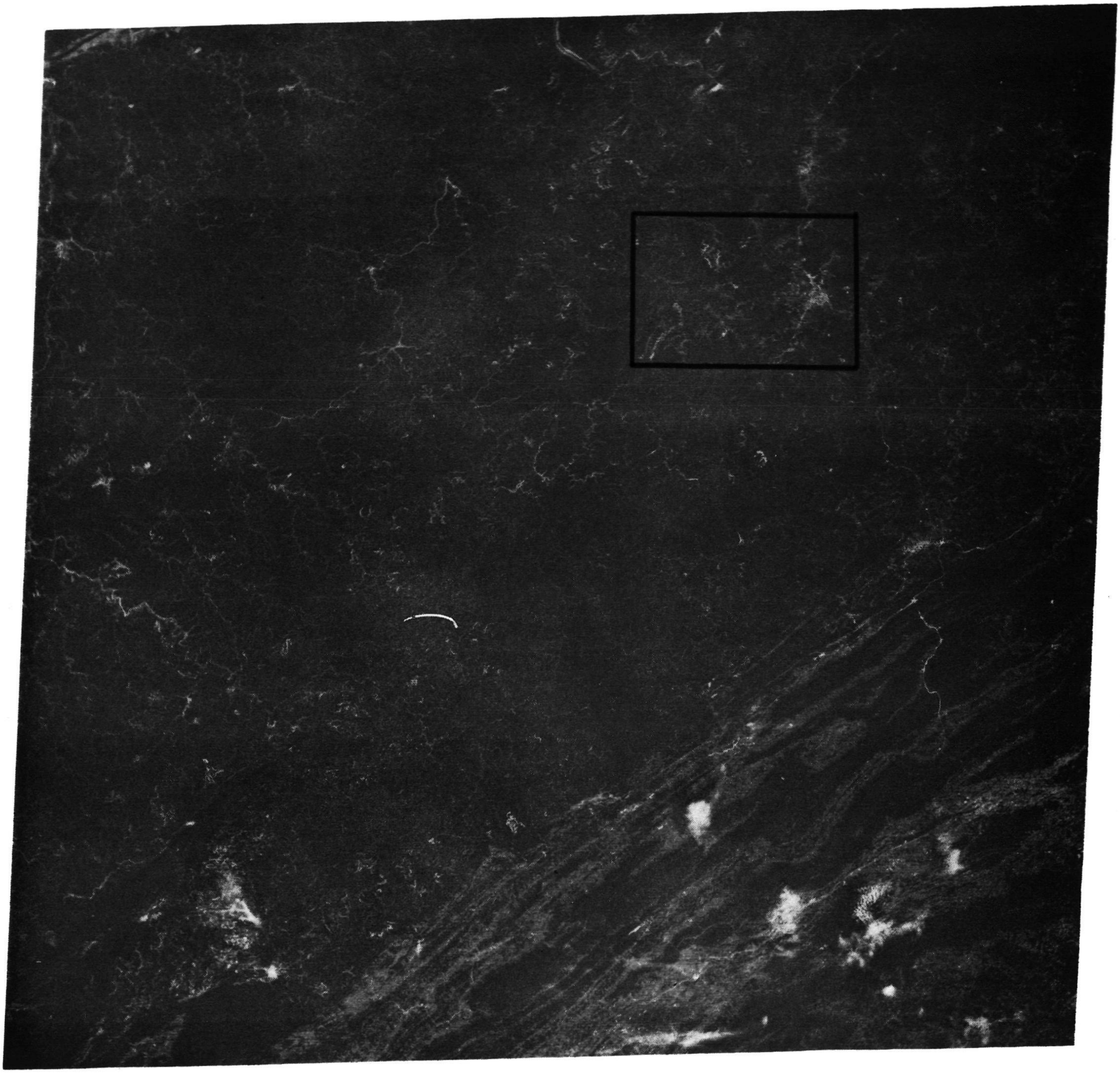


FIGURE 5.5-1 Landsat-2 MSS-7 Image (ID No. 2457-15203-01) 23 April 1976, showing the surface mine test site area on Coal Mountain near Beckley, West Virginia.

1976 show that at least three separate classes of information could be interpreted.

Each class was organized by grouping light intensity information for band 5 shown on the computer shade print. The classes were then compared to the color aerial photo base map classes for verification of accuracy. Table 5.5.4-4 illustrates that the three information classes were:

(a) V1- A class for areas within the test site with less than 50 percent coverage of vegetation.

(b) V2- Area within the test site with greater than 50 percent coverage of vegetation.

(c) A2- Bare soil areas within the test site.

Several of the techniques that were used to make the 1:250,000 scale satellite image color composites designed to highlight surface mines proved to be satisfactory for regional analysis maps. The best images for interpretation were the computer enhanced standard color infrared composite of bands 4, 5 and 7, and the photographically enhanced three color composite produced by exposing bands 5 and 7 normally, and splitting the band 4 exposure between bands 5 and 7 to render vegetation in tones of green to cyan and strip mines in tones of pink. These images could be used for regional planning purposes designed to locate abandoned or reclaimed surface mine areas for recreation development purposes.

The last Landsat product for the surface mine project, which was the computer enhanced color composite satellite image made from data collected April 23, 1976 and enlarged to scales of 1:24,000 and 1:48,000 showed various color combinations within the surface mine test site area which could have been related to the three classes of information found on the band 5 computer shade print. However, due to an exhaustion of funds for this project, a comparative class and acreage estimate study was not made. More work needs to be done with related techniques of this type.

5.5.6 Use of the Project

Two primary applications of information studied during this investigation about surface mines could possibly be used by the Department of Natural Resources for regional recreation planning and surface mine inventories.

The Landsat color composite images at a scale of 1:250,000 could be used to identify bare soil areas around existing or proposed recreation sites. The satellite images illustrate a regional view of West Virginia which can stimulate new ideas when planning recreation facilities.

A system for using remote sensing techniques for surface mine inventories could be organized in the following manner.

1. *Inventory some of the surface mines in the state by using aerial photography. (The Department of Natural Resources has established a good data bank.)*

2. Classify them as to:

   (a) barren ground

   (b) revegetated

   (c) abandoned

3. Use computer enhanced Landsat imagery to update base maps and monitor the mining and reclamation progress on an annual schedule.

Other research by Arthur Anderson, Orville Russell and David Nichols indicate that somewhat better results for internal surface mined land classification can be obtained by using different approaches (i.e., band ratioing and manual interpretation of computer processed Landsat imagery.

Although the Department of Natural Resources cannot use these techniques at this time for its primary reclamation inspection programs, it might be beneficial for studies concerning abandoned surface mine studies.

5.6 Remote Sensing Workshops and Handbook

Modern remote sensing concepts will undergo a period of evaluation before they are adopted as useful tools by the "user community" consisting of foresters, geologists, hydrologists, land cover planners, environmentalists, agriculturalists, etc.

The objective of public education, and the development of a team of remote sensing technicians within the Department of Natural Resources and other agencies, was a primary concern of the Landsat Program, because without it, the value of the work through the program would not be given a fair evaluation.

In order to take full advantage of the opportunity to work with the Landsat System, the Department of Natural Resources and West Virginia University jointly sponsored two workshops open to other agencies, which would give potential users in West Virginia the opportunity to listen and learn about remote sensing systems, applications, and programs which are using the technology in the state. The workshops were held in May, 1976 in Charleston and Morgantown, West Virginia, with good response and representation from 50 attendants of various interest groups such as the U. S. Fish and Wildlife Service, U. S. Forest Service, Regional Planning Councils, The Heritage Trust Program, USDA Soil Conservation Service, U. S. Army Corps of Engineers, U. S. Bureau of Mines, college and university professors, college students and the Department of Natural Resources.

The Remote Sensing Handbook was an attempt to record the information from the presentations given at the workshops and to provide additional information which could be used by any person interested in remote sensing. Hopefully, the handbook will contribute to the efforts of many people in the state who wish to establish open communications between public and private agencies who are using various forms of remote sensing technology. The following outline describes the information offered in the handbook:

A. An Introduction to Remote Sensing of Natural Resources

B. Satellite and Aerial Imagery of West Virginia

C. The Production of Orthophoto Maps

D. Interpretation of Geological Features from Imagery

E. Civil Engineering Applications of Remote Sensing

F. A Perspective View of the Landsat Program

G. The West Virginia Department of Natural Resources Landsat Program

H. Ecological Applications of Imagery

I. Forestry Applications of Aerial Photographs

J. Imagery and Aerial Photography Applications for Soil Surveys

K. The Land Use Data and Analysis Program (LUDA) in West Virginia

L. Mapping Landslide-Prone Areas Using Aerial Photography

M. Aerial Photography and Satellite Image Illustrations

N. Supplementary Materials (Pamphlets, etc.)

1. Landsat Inventory of Surface-Mined Areas Using Extendible Digital Techniques (authors: Anderson, Schultz, Buchman)

2. A Land Use and Land Cover Classification System for Use with Remote Sensor Data (USGS Paper #964)

3. The Earth Resources Observation System (EROS) Pamphlet. (USGS)

O. A List of Remote Sensing Reference Materials

P. A List of Remote Sensing Workshop Attendants

Seventy-five copies of the handbook have been printed and will be distributed to workshop attendants and appropriate agencies within the state.

6. SECONDARY PROJECTS

6.1 Introduction to the Secondary Project Concept

The Department of Natural Resources has started to develop "in house" remote sensing capabilities by working with some of the various divisions of the DNR to try and determine how remote sensing techniques can be of benefit in the future. The main drive to activate remote sensing with the DNR will come after the final report for Landsat Investigation #21260 has been completed.

In the near future, each division of the DNR will be asked to discuss situations concerning various projects they are involved with that could possibly utilize remote sensing techniques.

The secondary projects which were started during this Landsat Investigation are ones which will provide the foundation to develop further remote sensing capabilities within the DNR and other agencies within the state.

The process of adopting new technology into an established government system such as the DNR is a gradual and slow process which could take several months or even years.

6.2 Interpreted Satellite Image Maps of the State

In order to familiarize people with the Landsat Satellite System, satellite imagery, and various applications of Landsat, the DNR is making a set of 1:250,000 scale false color composite satellite image maps to cover most of the area in West Virginia. October imagery is being used to produce the maps which will show Level I Land Cover Classes (USGS Pamphlet #964) as delineated by manual interpretation techniques by DNR personnel. The following Landsat images will be used for the maps:

(a) October 25, 1973 ID No. 1461-15343-02

(b) October 26, 1973 ID No. 1460-15284-01

(c) October 27, 1973 ID No. 1461-15343-01

(d) October 22, 1974 ID No. 1821-15245-01

Each satellite image map will have two clear mylar overlays which show water bodies, major cities, county boundary lines, agricultural land, forested land, wetlands, and barren land. Also, a brief pamphlet describing the Landsat System will be issued with each map.

Potential users for the maps would include educational institutions, conservation organizations, recreation organizations, land use agencies, the Department of Commerce, and the Department of Natural Resources.

6.3 State Land Inventory Projects

Vegetation inventories are being conducted in various state parks and forests by graduate students from colleges in West Virginia. These projects are sponsored by the Department of Natural Resources which provides support for the three students working on the project's high altitude color infrared photography, low altitude color and color infrared photography.

The techniques which are being used for the vegetation inventory projects involve remote sensing to interpret information from various photographs, and to correlate information learned from ground studies to what can be learned from the photographs.

The procedures that are used to conduct the inventories will vary according to the students' preferences, but an outline (illustrated in Figure 6.3-1) can be set up to show the basic stages of a project's development.

(a) Aerial photography is chosen for the project, including a stereo pair of high altitude color infrared photographs taken on December 3, 1973, at 1:125,000 scale. These photos will be used to provide a three dimensional view of the test site area, inventory evergreen vegetation, locate land features (roads, buildings, water bodies, etc.) and to help locate vegetation patterns at different elevations which may not plainly show on the photographs but have been found in similar physiographic areas by field studies.

(b) The next step is to make a photo-enlarged base map at a scale of 1:24,000 or 1:32,250 from one of the U-2 photographs of the test site area. This will serve as a "data base" for information gathered from low altitude color, color infrared, and black-and-white photographs, topographic maps, and field studies.

(c) After the photo-enlargement is made, land feature delineations and topographic elevations can be put on the photograph as an overlay which will serve as reference information for the vegetation inventory.

(d) The first type of vegetation to be delineated on the photo base map would be the evergreens which are shown very clearly on infrared photography.

(e) After the evergreens are located, ground surveys should be made in strategic locations to record representative plan communities, plant genera, and plant species which exist. It is important to pick the areas to be field surveyed in a manner that will provide vegetation information which will be representative of the total test site. Various methods for the field surveys can be used

as described in books such as: Vegetation Mapping, by A. W. Kuchler; The Description and Classification of Vegetation, by D. W. Shimwell; and Methods of Vegetation Study, by E. P. Phillips. The vegetation classification system that is used should be complementary with the West Virginia Heritage Trust Program's data base illustrated in Table 6.3-2 which is being used to provide the basis for gathering and storing information about West Virginia's flora and fauna.

(f) The correlation of the information obtained from the field studies with a knowledge of vegetation habitat characteristics, the information on the photo base map concerning various elevations, and physiographic features can be used to complete the vegetation maps of the test site area. The vegetation maps are displayed on the color infrared photographs in a series of overlays.

Various state land inventory projects have already been completed, such as Kanawha State Forest, North Bend State Park, Holly River State Park, Pipestem State Park, and Lost River State Park with the aid of the remote sensing system.

Other areas which have been inventoried, or will be, include two areas not owned by the state (Gaudineer Scenic Area and Blennerhassett Island), Watoga State Park, and two public hunting and fishing areas (Nathaniel Mountain and Sleepy Creek).

Hopefully, other agencies in the state will be able to use the techniques adopted by the DNR for doing detailed small area vegetation cover type studies.

FIGURE 6.3-1 STATE LAND INVENTORY OUTLINE

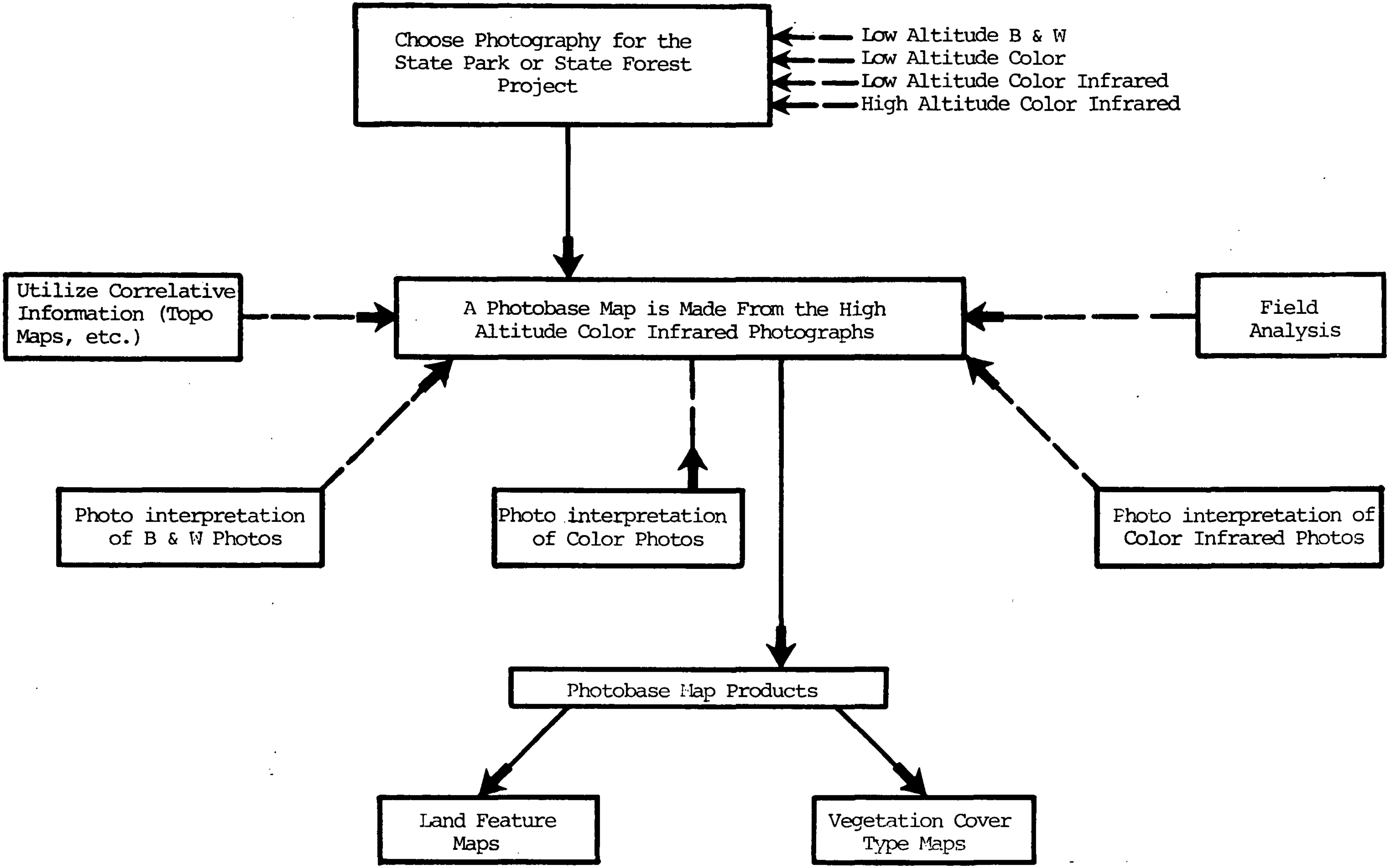


TABLE 6.3-2

THE HERITAGE TRUST PROGRAM PLANT CLASSIFICATION SYSTEM

PLANT COMMUNITIES

(Non-Forest)

00.000 Undefined Non-Forest

01.000 Grassland

- 01.001 Grass Bald

02.000 Cliff and Ledge Herbaceous Communities

- 02.002 Limestone Cliff and Ledge Vegetation
- 02.001 Sandstone Cliff and Ledge Vegetation

03.000 Shrubland

- 03.002 Alder Thicket
- 03.001 Heath Barren
- 03.003 Spirea Thicket
- 03.004 St. John's-wort Thicket

04.000 Marsh

- 04.001 Cattail Marsh
- 04.002 Rush Marsh
- 04.003 Sedge-Grass Marsh

05.000 Wet Meadow

- 05.001 Rush Wet Meadow
- 05.002 Sedge-Grass Wet Meadow

TABLE 6.3-2 (cont'd)

THE HERITAGE TRUST PROGRAM PLANT CLASSIFICATION SYSTEM

(Non-Forest) (cont'd)

06.000 Bog and Fen

- 06.001 Polytrichum Moss Fen
- 06.002 Polytrichum Moss-Blueberry-Black Chokeberry Fen
- 06.003 Polytrichum Moss-Rubus Fen
- 06.004 Polytrichum Moss-Rush Fen
- 06.005 Polytrichum Moss-Sedge-Grass Fen
- 06.006 Sphagnum Moss-Cranberry-Black Chokeberry Bog
- 06.007 Sphagnum Moss-Sedge-Grass Bog
- 06.008 Sphagnum Bog

(Forest)

10.000 Undefined Forests

11.000 Northern Coniferous Forests

- 11.007 White Cedar Forest
- 11.006 Mixed Conifer-Hardwood Swamp Forest
- 11.001 Red Spruce Forest
- 11.004 Red Spruce-Balsam Fir Forest
- 11.005 Red Spruce-Balsam Fir-Hemlock Forest
- 11.002 Red Spruce-Hemlock Forest
- 11.003 Red Spruce-Yellow Birch Forest
- 11.008 Red Pine Forest

TABLE 6.3-2 (cont'd)

THE HERITAGE TRUST PROGRAM PLANT CLASSIFICATION SYSTEM

12.000 Northern Hardwood Forests

- 12.010 Appalachian Oak Forest
- 12.003 Beech Forest
- 12.002 Beech-Maple Forest
- 12.005 Black Cherry Forest
- 12.011 Dwarfed Hardwoods Thicket
- 12.007 Hemlock Forest
- 12.006 Hemlock-Hardwood Forest
- 12.004 Sugar Maple Forest
- 12.001 Northern Hardwoods Forest
- 12.009 White Pine Forest
- 12.008 White Pine-Hemlock Forest

13.000 Central Hardwood Forests: Xeric

- 13.001 Chestnut Oak Forest
- 13.004 Oak-Hickory Forest
- 13.005 Oak-Pine Forest
- 13.006 Pine Forest
- 13.002 Scarlet Oak-Black Oak Forest
- 13.003 Scrub Oak Thicket
- 13.007 Shale Barren Vegetation

14.000 Central Hardwood Forests: Mesic

- 14.001 Mixed Mesophytic or Cove Hardwood Forest
- 14.005 Northern Red Oak Forest
- 14.006 Red Oak-Basswood-White Ash Forest

TABLE 6.3-2 (cont'd)

THE HERITAGE TRUST PROGRAM PLANT CLASSIFICATION SYSTEM

14.004 White Oak Forest

14.002 Yellow Poplar Forest

14.007 Yellow Poplar-Hemlock Forest

14.003 Yellow Poplar-White Oak-Red Oak Forest

15.000 Central Hardwood Forest: Hydric

15.001 Black Willow Forest

15.005 Bottomland Moist Mixed Hardwoods Forest

15.002 Cottonwood Forest

15.003 River Birch-Sycamore Forest

15.004 Silver Maple-American Elm Forest

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary Based on Primary Project Results

The primary projects which have been conducted during this investigation yielded a variety of information which should be useful to various interest groups within the Department of Natural Resources, other agencies within the state, and NASA. Although some of the methods of processing and evaluating Landsat imagery did not prove to be useful for recreation applications, the results from these attempts will provide information for the development of a more useful Landsat System.

The Landsat II System has proven to be useful for providing images of large areas of the state which can be used by recreation planners or environmentalists to show physiographic, cultural, and environmental features in West Virginia which are not readily apparent from other types of imagery.

The use of Landsat computer classification techniques, which were not extensively used in this investigation, would increase the utility of the system far beyond the capabilities we have demonstrated during this study. An open mind should be kept to the possibilities of using computer classification techniques with future Landsat Systems.

One of the most important things which has been learned during this investigation has been the realization of the potential for using various kinds of remote sensing technology for earth resource applications. Hopefully, various interest groups within the Department of Natural Resources will start to utilize some of the ideas which have resulted from this investigation.

The objectives of this investigation have been met in the following manner.

(a) *The development of a recreation resource data base consisting of annotated resource maps and reference imagery has been established by the use of the Satellite Image Mosaic of West Virginia, Landsat image maps made from October imagery at a scale of 1:250,000 and a file of high altitude color and color infrared photography taken in December 1973, October 1975 and February 1976. This data base will be available for use by all organizations in the state.*

(b) *The Canaan Valley-Dolly Sods project fulfills the objective of differentiating ecozones within a mountain area based on geological, vegetative and hydrological inter-relationships. Canaan Valley was a very good area to study and the products of the project will be quite useful.*

(c) *The objective to map land use patterns and ecologically unique natural resources within ecozones to support effective state land acquisition and protection programs intended to preserve selected resource areas was achieved by doing the Wetlands Study and the Canaan Valley-Dolly Sods project. Hopefully, the results of this project will contribute information which will be useful for determining whether the area should be saved as a unique natural area of the state or made into a water reservoir. Much controversy has arisen concerning this area, and, hopefully, remote sensing can be of service.*

(d) *A relatively small test site was chosen for a surface mine inventory study. It was felt that if the developed techniques*

for using satellite imagery proved to be of "operational" nature, then more of the state could be studied at a later date. Landsat was able to distinguish three classes of information about the test site, with results which closely matched the high altitude color aerial photography base map. Also, Landsat images were made to show the bare soil areas which exist in the southern part of West Virginia. More work needs to be done by the Department of Natural Resources to determine more ways in which remote sensing can be useful for surface mining studies.

(e) The recreation resource data base can be used for preparing or reviewing regional environmental impact judgments concerning local and regional recreation areas within the state. The Department of Natural Resources' data base has almost complete photographic coverage of all the state parks and forests, and most of the ecologically unique areas in the eastern half of West Virginia.

(f) The objective of developing a team of experienced Landsat data users has not been fully completed. Various workshops have been held for Department of Natural Resources' personnel, but more work will have to be done to determine the ways in which the various divisions of the Department of Natural Resources can use remote sensing techniques.

A plan to implement modern remote sensing technology into the Department of Natural Resources has been organized as shown in Figure 7.1-1 entitled: A Landsat Remote Sensing Development and Implementation Chart. The multistage approach to remote sensing would be used involving satellite imagery, high altitude aerial photography, and low altitude aerial

photography depending on the objectives of the projects to be done. The remote sensing team could serve as a service unit of the Department of Natural Resources to benefit the various activities like Forestry, Parks and Recreation, the Public Land Corporation, Surface Mine Reclamation, Water Resources, Environmental Assessment, Fish and Wildlife Resources and Women and Youth Activities. The Landsat System may not be of direct benefit to every division of the Department of Natural Resources, but some form of remote sensing technology could be helpful.

Remote sensing is a very young science which needs a little more time. It is predicted that the 1980's will see the appearance of an advanced Landsat and other remote sensing system which will be very useful for recreation resource planning and many other applications in West Virginia.

7.2 Summary Based on the Secondary Project Results

The secondary projects which have been started by the Department of Natural Resources will provide the basis for the development of a remote sensing "in house" capability between the different divisions of the DNR.

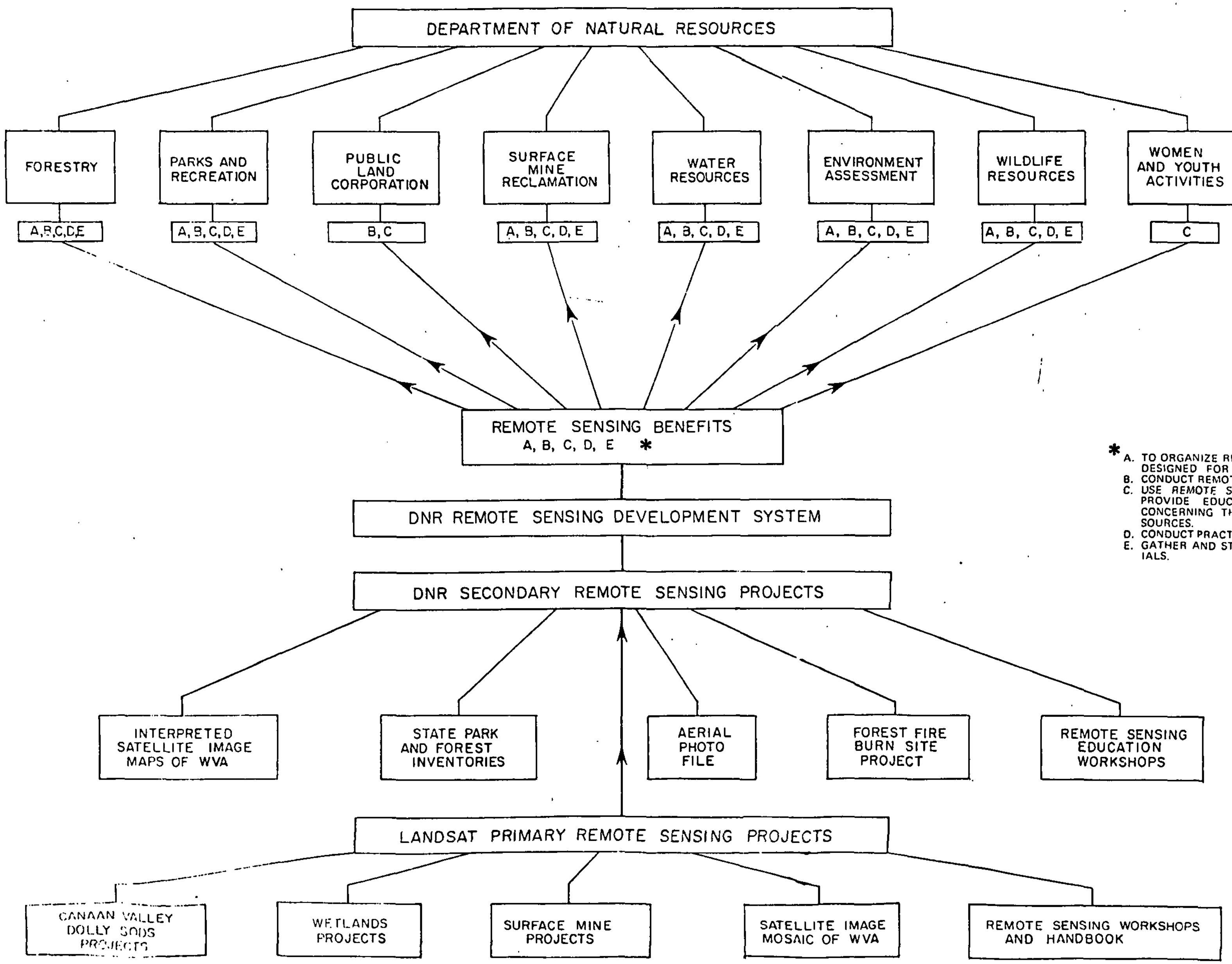
The photofiles of the various kinds of photography can be used for future remote sensing projects and the training of photo interpreters along with the aerial photography techniques which have been developed for 35mm and 70mm color and color infrared photography.

The work that has started with the State Parks Naturalist Program should continue, with more of the parks doing land cover mapping and using Landsat, and high altitude imagery for environmental education projects.

The landsat bulk processed false color composite 1:250,000 scale land cover maps made from October imagery should provide the environmental interest groups in the state with good base maps to use when studying about different scientific disciplines like geology, botany, hydrology, forestry,

FIGURE 7.1-1

LANDSAT REMOTE SENSING DEVELOPMENT AND IMPLEMENTATION CHART



* A. TO ORGANIZE REMOTE SENSING SYSTEMS DESIGNED FOR SPECIFIC APPLICATIONS.
B. CONDUCT REMOTE SENSING STUDIES.
C. USE REMOTE SENSING TECHNIQUES TO PROVIDE EDUCATIONAL INFORMATION CONCERNING THE USE OF NATURAL RESOURCES.
D. CONDUCT PRACTICAL RESEARCH.
E. GATHER AND STORE REFERENCE MATERIALS.

agriculture, and land use planning. Copies of the original Landsat maps can be sold to the public so that the DNR will have additional funds to use for remote sensing projects and equipment.

These initial efforts at establishing remote sensing as a system for gathering information about the environment should be followed by additional experimentation and applied research efforts.

After Landsat Investigation No. 21260 has been completed, a meeting will be held involving all of the various potential remote sensing interest groups with the DNR and other agencies. The purpose of the meeting will be to explain in more detail about the concepts of the multistage approach to remote sensing; review the Contribution of Landsat to Natural Resource Protection and Future Recreational Development in the State of West Virginia Project proposal; explain the results of the Landsat Investigation' discuss future applications of Landsat in West Virginia; discuss future spacecraft remote sensing systems; and present a plan for actively using remote sensing techniques in the DNR.

Each interest area of the DNR will then evaluate the ideas and techniques, and decide how they want to utilize Landsat and other remote sensing techniques.

7.3 Advantages and Limitations of Landsat Data

The Landsat II System, which is designed for analyzing large areas of the surface of the earth, has several virtues which make it useful for regional recreation planning and land cover analysis. The repetitive coverage of the satellite over any given geographic area every nine days enables planners to obtain information at appropriate time intervals. Also, the 100-115 mile square area that is covered by one satellite image gives the planner a view of an area the size of several counties in West Virginia.

The land use or recreation planner can use this type of imagery for analyzing area situations which may not be readily apparent from other information sources.

Landsat now has the ability to gather information concerning land cover for Level I Categories as described in the USGS Professional Paper #964 entitled A Land Use and Land Cover Classification System for Use With Remote Sensor Data (shown in Table 7.3-1).

The Landsat II Investigation has provided the Department of Natural Resources with a variety of useful information, but until the capabilities of the satellite are improved to a level similar to those outlined for Landsat-D, the information obtained from manual interpretation techniques of satellite imagery demonstrated in this investigation will not be of primary importance to recreation planning in West Virginia.

As further advances in technology are made, it may be necessary to modify the USGS land cover classification system for use with automatic data analysis. The Landsat-D mission should increase the amount of detail that can be classified to Level II as shown in Table 7.3-1. If this can be achieved, then the recreation or land use planner will have a valuable information source to use.

7.4 Recommendations for Future Projects or Studies

7.4.1 Technological Recommendations

West Virginia is a mountain state which is approximately 70 percent covered with forest vegetation. The state's economy relies a great deal on forest products, coal resources, and industrial manufacturing.

TABLE 7.3-1

LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR

USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
1 Urban or Built-up Land	11 Residential. 12 Commercial and Services 13 Industrial 14 Transportation, Communications, and Utilities. 15 Industrial and Commercial Complexes. 16 Mixed Urban or Built-up Land. 17 Other Urban or Built-up Land
2 Agricultural Land	21 Cropland and Pasture. 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas. 23 Confined Feeding Operations. 24 Other Agricultural Land
3 Rangeland	31 Herbaceous Rangeland. 32 Shrub and Brush Rangeland. 33 Mixed Rangeland
4 Forest Land	41 Deciduous Forest Land. 42 Evergreen Forest Land. 43 Mixed Forest Land.
5 Water	51 Streams and Canals. 52 Lakes. 53 Reservoirs. 54 Bays and Estuaries.
6 Wetland	61 Forested Wetland 62 Nonforested Wetland
7 Barren Land	71 Dry Salt Flats. 72 Beaches. 73 Sandy Areas other than Beaches 74 Bare Exposed Rock. 75 Strip Mines, Quarries, and Gravel Pits. 76 Transitional Areas 77 Mixed Barren Land

TABLE 7.3-1 (CONT'D)

LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR

USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
8 Tundra	81 Shrub and Brush Tundra. 82 Herbaceous Tundra. 83 Bare Ground Tundra. 84 Wet Tundra. 85 Mixed Tundra.
9 Perennial Snow or Ice	91 Perennial Snowfields. 92 Glaciers.

If spacecraft remote sensing systems are going to be more beneficial to West Virginia, they should be technically organized to emphasize the analysis of vegetation cover and land cover analysis.

In many cases, information about soil and subsurface characteristics, drainage patterns, and environmental impact of pollutants can be derived through the identification of the type and condition of vegetation coverage, thereby expanding the value of the analysis to users outside of agriculture and forestry. Therefore, a sensor designed for analysis of vegetation can form a basis for a general purpose remote sensing system.

Identification of any particular cover type generally requires not more than four spectral bands (if it can be discriminated at all), multicategory classification tasks can beneficially use more than four bands from which to choose those best suited to discriminate each category. The six bands shown in Table 7.4.1-1, covering a spectral range from the "green" (approximately 0.54 um) to the "thermal-infrared" (approximately 4.0 um to 14.0 um), would seem to represent those best suited for discrimination of vegetation cover types in support of a variety of applications.

In general, users of land use information are unlikely to provide definitive preferences as to the spectral location, width, sensitivity of spectral bands in most remote sensing

systems. Spectral response in any wavelength region is not uniquely sensitive to types or patterns of human activities. For the most part, it is spatial distribution, size, and proximity to other features that characterize most types of development and allows their identification. Bands chosen to optimize analysis of vegetation, soil, rock types, water resources, etc., can all contribute to a system for effective land use inventory and recreation planning which should be very important to West Virginia in the future.

Another modification to the Landsat System would be improvements in resolution (smaller instantaneous field of views) over the MSS IFOV of 80m. Experience indicates that detailed vegetation analysis and complete Level II mapping would require ground IFOV of roughly 10-30m. The system outline for Landsat-D shows a characteristic of 30m resolution and a spectral response range which should be quite adequate for vegetation and land cover mapping.

The interference of cloud cover over West Virginia can be a problem for studies requiring a short frequency of coverage like disaster damage analysis and crop analysis, but many significant applications do not require less than nine day coverage for information. Therefore, this investigation recommends the nine day coverage of the Landsat System.

TABLE 7.4.1-1

SPECTRAL BAND SELECTION FOR VEGETATION ANALYSIS

BAND	GENERAL APPLICATION
0.53 to 0.59 um	Discrimination of vegetation.
0.58 to .63 um	Vigor determination, disease detection, forest type discrimination.
0.62 to 0.68 um	Species discrimination, vigor determination.
0.76 to 0.90 um	Species discrimination, vigor determination biomass determination.
1.55 to 1.75 um or 2.0 to 2.6 um	Detection of moisture stress.
4.5 to 5.5 um or 8.0 to 14.0 um	Detection of moisture stress, soil moisture, some species discrimination

7.4.2 *Ideas for Future Satellite Remote Sensing Projects in West Virginia*

A variety of Landsat applications, which could be useful in West Virginia, have not been demonstrated or fully developed. Hopefully, the Department of Natural Resources and other agencies within the state will start applying Landsat to more of these opportunities.

The first ideas concerning the use of Landsat Satellite Systems in the near future will be centered around the Landsat II and Landsat-C Systems, which will be in operation until 1980.

Landsat Investigation No. 21260 (The Contributions of Landsat to Natural Resources Protection and Future Recreational Development in the State of West Virginia) has demonstrated some of the ways that Landsat imagery can be used for regional recreational planning. Many of the regional planning councils in the state can probably use some of the techniques demonstrated by the DNR for making regional land cover maps.

The next application which should be emphasized is surface mine analysis. The results from the DNR surface mine project indicates that Landsat has the capability to provide useful information about surface mines. More work needs to be done to develop a system for using Landsat in the Reclamation Division of the DNR. Computer classification techniques which have not been tried in West Virginia would provide a more rapid

means of analysis. Remote sensing data can aid substantially in planning for orphan mine land reclamation under the new law HR-2 or S-7.

Another application for Landsat would be to aid in the evaluation of natural disasters that occur in the state. The satellite system has been used on a variety of draught analysis and water pollution projects in other parts of the country.

The Forestry Division of the DNR is sponsoring a project to demonstrate Landsat capabilities for monitoring and evaluating forest fire burned sites in the state. Similar studies have been done before in other parts of the country with positive results. Most of the previous studies have been set up to provide information concerning the location, area, and intensity of forest fires. This type of application could be very useful in West Virginia.

NASA has proposed a program to extend the flow of orbital earth observation data into the mid-1980's and to upgrade the quality of that data consistent with advances in technology which have occurred since the initial Landsat's were designed. Following the launch of Landsat-C, carrying a modified version of the MSS already flown with Landsats I and II and modular RBV's having 40m IFOV's, the proposed program calls for the development of an observation system incorporating the latest state of the art in visible - IR scanner, data processing, and spacecraft technology.

The principal component of the mission is an advanced MSS - the "thematic mapper" (T/M). The design specifications for the T/M system call for extension of the capability of the present Landsat's in virtually every significant aspect - the range of spectral coverage, number and sensitivity of individual spectral bands, ground resolution, quantization and geometric accuracy. The primary objective of the T/M program is observation of land cover characteristics - in particular, vegetation. While not excluding other compatible objectives, the observation of vegetation combines both techniques of multispectral analysis and the probability of extensive utility in a variety of applications. After an initial period of user adjustment and experimentation with the new system, the T/M is to provide the basis for transition to operational earth resource observation from space.

A variety of technical improvements will enable users to obtain more detailed information at a much faster rate. Two significant improvements will be the T/M 30 meter resolution and the four-day turnaround time for receiving data. The following outline illustrates some of the information capability improvements which should be possible.

(a) Mapping of small farm ponds and water impoundments as small as one acre in size.

(b) Smaller fields resolved from 10 hectares to 1.5 hectares.

(c) Improved soils mapping capability.

(d) Improve timber volume estimation to approximately $\pm$ 5 percent at 80 percent confidence

(e) *Forest type mapping at Level II (reference section 7.3 for chart) from ± 15 percent to ± 5 percent of aerial accuracy.*

(f) *Permit identification of additional subcategories, e.g., vegetation species, separation of urban subcategories, for more detailed urban/suburban, wildlife habitat, wetlands and coastal zone surveys.*

(g) *Improve ability to define irregular and other strip mining areas with greater accuracies.*

(h) *Reliable change detection and monitoring of land cover units down to one acre.*

(i) *Flooded areas and boundaries should be delineated on 1:24,000 - 1:62,500 scale.*

(j) *Dredging, lagooning, etc., will be better observed.*

(k) *The ability to monitor some types of agricultural crops.*

The 1980 capabilities of Landsat should be very useful to many agencies in West Virginia, and the time to start developing the ability to handle this type of technology is now!

REFERENCES

Core, Earle W. Vegetation of West Virginia. McClain Printing Co., Parsons, West Virginia, 1966. (217 pp)

Fortney, Ronald H. The Vegetation of Canaan Valley, West Virginia: A Taxomonic and Ecological Study. Dissertation, West Virginia University, Morgantown, West Virginia, 1975. (210 pp)

Heath, Gordon R. A Comparison of Two Basic Theories of Land Classification and their Adaptability to Regional Photo Interpretation Key Techniques. Photogrammetric Engineering, Vol. 26, 1970. (pp 101-111)

Kan, E. P. and R. D. Dillman. Timber Type Separability in Southeastern U. S. on Landsat-1 MSS Data. Proceedings - NASA Earth Resources Survey Symposium, Houston, Texas, June, 1975. (135 pp)

Kuchler, A.W. Vegetation Mapping. Ronald Press, Inc., New York, 1967. (472 pp)

National Academy of Science. Report of the Panel on Agriculture, Forest and Range to the Space Applications Board, Academy of Engineering, Supporting Paper No. 4. National Academy of Sciences, Washington, D. C., 1975. (47 pp)

-----. Report of the Panel on Land Use Planning to the Space Applications Board of the National Academy of Engineering, Support Paper No. 3. National Academy of Sciences, Washington, D. C., 1975. (55 pp)

National Research Council, Committee on Remote Sensing Programs for Earth Resource Surveys. Resource and Environmental Surveys from Space with the Thematic Mapper in the 1980's. National Academy of Sciences, Washington, D. C., 1976. (121 pp)

-----. Space Applications Board of the Assembly of Engineering, Practical Applications of Space Systems. National Academy of Sciences, Washington, D. C., 1975. (65 pp)

Thornbury, William D. The Principles of Geomorphology. Wiley and Sons Company, Inc., New York, 1969. (pp 135-150)

-----. Regional Geomorphology of the United States. Wiley and Sons Company, Inc., New York, 1967. (pp 50-100)

U. S. Department of the Interior, Geological Survey. A Land Use Classification System for Use with Remote Sensor Data by James R. Anderson, et al., (USGS Report No. 964) Government Printing Office, Washington, D. C., 1972.

REFERENCES

West Virginia Highlands Conservancy. The Dolly Sods Area 32,000 Acres in and Adjacent to the Monongahela National Forest, West Virginia, revised edition, 1971. (pp 1-15)

National Academy of Science. Report of the Panel on Agriculture, Forest and Range to the Space Applications Board, Academy of Engineering, Supporting Paper No. 4, published by National Academy of Sciences, Washington, D. C., 1975. (47 pp)

Nichols, J. D. Mapping of the Wildland Fuel Characteristics of the Santa Monica Mountains of Southern California. Proc. NASA Earth Resources Survey Symposium, Houston, Texas, June 1975. (p 159)

Kan, E. P. and Dillman, R. D. Timber Type Separability in Southeastern U. S. on Landsat-1 MSS Data. Proc. NASA Earth Resources Survey Symposium, Houston, Texas, June 1975. (p 135)

National Academy of Science. Report of the Panel on Land Use Planning to the Space Applications Board of the National Academy of Engineering, Supporting Paper No. 3, published by the National Academy of Sciences, Washington, D. C., 1975. (55 pp)

Committee on Remote Sensing Programs for Earth Resources Surveys. 1976 Resource and Environmental Surveys from Space with the Thematic Mapper in the 1980's.

Space Applications Board of the Assembly of Engineering - National Research Council. Practical Applications of Space Systems. 1975 publication, National Academy of Sciences. (49 pp)